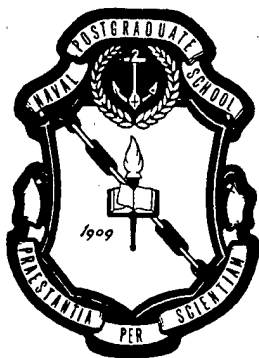


Naval Postgraduate School  
Monterey, California 93943-5138



# ***SUMMARY OF RESEARCH 1996***

## **Department of Operations Research**

**CAPT Frank C. Petho, USN  
Acting Chair**

**Gerald Brown  
Associate Chair for Research**

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Prepared for: Naval Postgraduate School  
Monterey, CA 93943-5000

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**NAVAL POSTGRADUATE SCHOOL**  
**Monterey, California**

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Superintendent

R. Elster  
Provost

This report was prepared for the Naval Postgraduate School, Monterey, CA.

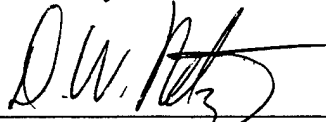
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**REPORT DOCUMENTATION PAGE**

Form approved

OMB No 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

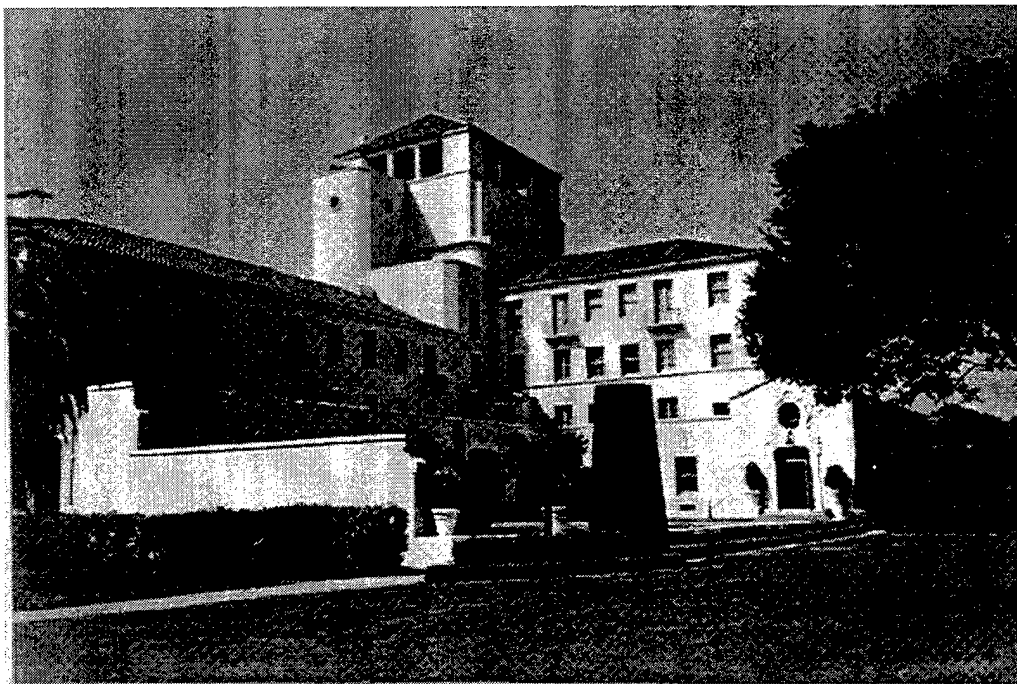
<b>1. AGENCY USE ONLY (Leave blank)</b>		<b>2. REPORT DATE</b> November 1997	<b>3. REPORT TYPE AND DATES COVERED</b> Summary Report, 1 January 1996 - 31 December 1996	
<b>4. TITLE AND SUBTITLE</b> Summary of Research 1996, Department of Operations Research			<b>5. FUNDING</b>	
<b>6. AUTHOR(S)</b> Faculty of the Department of Operations Research, Naval Postgraduate School				
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> Naval Postgraduate School Monterey, CA 93943-5000			<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  NPS-09-97-011	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> Naval Postgraduate School Monterey, CA 93943-5000			<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>	
<b>11. SUPPLEMENTARY NOTES</b>  The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
<b>12a. DISTRIBUTION/AVAILABILITY STATEMENT</b>  Approved for public release; distribution is unlimited.			<b>12b. DISTRIBUTION CODE</b>  A	
<b>13. ABSTRACT (Maximum 200 words.)</b>  This report contains summaries of research projects in the Department of Operations Research. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.				
<b>14. SUBJECT TERMS</b>			<b>15. NUMBER OF PAGES</b> 60	
			<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b> Unclassified	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b> Unclassified	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b> Unclassified	<b>20. LIMITATION OF ABSTRACT</b>	

**DEPARTMENT OF  
OPERATIONS RESEARCH**

**FRANK PETHO  
ACTING CHAIR**

## THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of US and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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## Preface

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance DoN/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

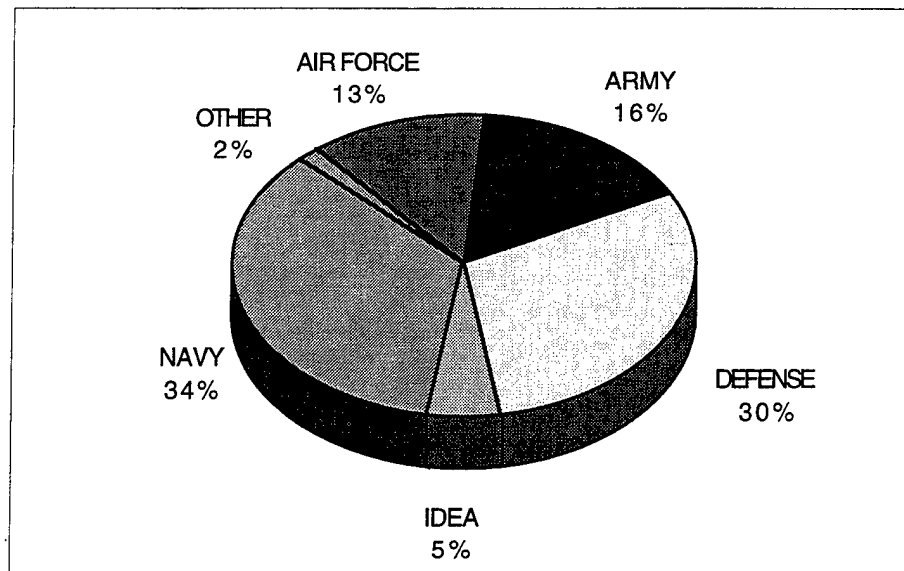
New technologies and policy changes will of course occur, necessitating changes in educational programs and stronger ties between the fleet and the support establishment. NPS must remain poised to face this challenge and to utilize emerging technologies and new policies within its curricula programs. Faculty, therefore, must stay abreast of these developments through a dynamic research program that helps fulfill the School's goals of excellence, uniqueness, and relevance.

The overall research program at NPS has three funded components. The Direct Funded Research and Institute for Joint Warfare Analysis Programs are institutionally funded within the School's operating budget. The Direct Funded Research Program is administered by the Associate Provost and Dean of Research. The Institute for Joint Warfare Analysis Program is administered by the Director of IJWA.

- The Direct Funded Research (DFR) Program provides funding to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Institute for Joint Warfare Analysis Research Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of faculty research.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The three research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

In 1996, the level of the research effort at the Naval Postgraduate School was 141 faculty workyears and exceeded 29 million dollars. Eighty percent of the research was funded by reimbursable sponsors and 20 percent was funded by the Naval Postgraduate School. Sixty-five percent of the work was performed for the Navy and the remainder was sponsored by other agencies, both DoD and non-DoD. A profile of the reimbursable program of the Department of Operations Research is provided in Figure 1:



Size of Program: \$1,909K

Figure 1. Department of Operations Research - Sponsor Profile

Research at NPS is carried out by faculty in the School's eleven Academic Departments, four Interdisciplinary Groups and the School of Aviation Safety. In the pages that follow, research summaries are provided for projects undertaken by faculty in the Department of Operations Research during 1996. An overview and faculty listing are provided as an introduction. A list of publications is also included, if applicable. Abstracts for thesis advised by department faculty in 1996 complete this research summary.

Questions about particular projects may be directed to the Faculty Principal Investigator listed, the Department/Group Chair, or the Department Associate Chair for Research. Questions may also be directed to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice) or [research@nps.navy.mil](mailto:research@nps.navy.mil) (e-mail).

August 1997



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## **DEPARTMENT SUMMARY**

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The research program in the Department of Operations Research seeks to advance the state of knowledge in key technology areas important to the Department of the Navy, Department of Defense, and military planning.

- Research is evaluated by three criteria: scholarship, relevance, and education.
- Scholarship is traditionally demonstrated by written research papers that appear in the open literature after peer review by experts in the field. Products of scholarship also include technical reports, student theses, reports to sponsors, and conference presentations.
- Relevance is evident when sponsors are willing to underwrite the cost of research. When sponsors or their clients use research results, the research gains importance.

Education is our primary mission: Research directly supports graduate instruction. Each graduate faculty member is required to have an earned doctorate degree, or equivalent, and is expected to conduct and to publish original scholarly research in his or her fields of graduate instruction. Research and publication are the hallmarks of demonstrated expertise and the foundations of a graduate academic department.

### **Research Mission Statement of the Operations Research Department**

Traditional basic research areas in the Operations Research Department include: Optimization; Probability and Stochastic Models; and Statistics and Data Analysis. In addition, we pursue related topics such as Human Systems Integration; Search, Detection, and Evasion; Games, Tactics, and Strategy; and War Gaming and Simulation.

### **The Operations Research Department operates a number of research laboratories:**

Human Systems Integration Lab, GI 221 (3,080sf):  
Computers, psychometric experimental equipment.

Learning Research Centers:  
GI-128 (952sf), GI-203 (1,080sf), GI-318 (960sf);  
Networked PC's and servers;  
Video display projectors;  
OR Departmental licensed software suite.

Optimization Lab, GI-206 (288sf):  
IBM RS-6000's, various computers and support hardware;  
Commercial optimization software suite for DoD internet access;  
topical thesis and publication library.

Operational Logistics Lab, GI 274 (160sf):  
Development and use of TACLOG models, logistics exercises;  
NAVY TAC 3 computer;  
topical thesis and publication library.

Statistics Lab, GI 221 (shared space):  
Computers, exploratory data analysis software.

Simulation Lab, GI 217 (600sf):  
Unix computers, visual displays, software.

Secure Computing and Simulation Lab, In 157 (3,400sf):  
Classified wargame facility;  
Sun SPARCstations, Silicon Graphics Indigo R4000, PC network.

The Operations Research Department also uses other research laboratories and equipment on campus by agreement with their managers, and uses classified research spaces.

## **DEPARTMENT SUMMARY**

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Operational problems are challenging and interdisciplinary, and research results often suggest applications. Some results are widely applicable and are generalized for a broader recognition.

The following summaries demonstrate the breadth and depth of the unclassified research program. Summaries of the classified research programs are available via appropriate authority.

## PROJECT SUMMARIES

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### LARGE-SCALE OPTIMIZATION

G.H. Bradley, Professor

G.G. Brown, Professor

R.K. Wood, Associate Professor

Department of Operations Research

Sponsor: Office of Naval Research

**OBJECTIVE:** This continuing research program develops optimization theory and algorithms to model and solve large-scale decision support problems.

**SUMMARY:** Stochastic network models have been enhanced, and more general results on bounds on solution quality of general stochastic linear programs have been established. Distributed network decision support has been investigated. New persistent optimization modeling and solution methods have been demonstrated. Recent Navy applications include incorporation of internet technologies in Joint Vision 2010, drug interdiction, program planning, berth assignment, and fleet scheduling.

### PUBLICATIONS:

Dell, R., Brown, G., and Wood, K., "Persistence and Optimization," Interfaces (forthcoming).

Wood, K., Cormican, K., and Morton, D., "Stochastic Network Interdiction," Operations Research (forthcoming).

Brown G., Cormican, K., Lawphongpanich, S., and Widdis, D., "Optimizing Submarine Berthing with a Persistence Incentive," Naval Research Logistics (forthcoming).

Wood, K., and Morton, D., "Restricted-Recourse Bounds for Stochastic Linear Programming," (manuscript in review).

Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," (manuscript in review).

Wood, K., and Morton, D., "Verifying Solution Quality in Stochastic Programs," (manuscript in review).

Wood, K., and Morton, D., "Efficient Solutions of a Stochastic Maximum Flow Problem," (manuscript).

Bradley, G., "Dynamic and Interactive Electronic Research Publications Using Java," February 1996, <http://dubhe.cc.nps.navy.mil/~gbradley/JavaPaper/versionsJava.html>.

Dell, R., Farmer, R., and Brown, G., "Scheduling Coast Guard District Cutters," Interfaces, 26, March-April 1996, pp. 59-72.

### CONFERENCE PRESENTATIONS:

Wood, K., and Morton, D., "Deterministic and Monte Carlo Bounding Techniques for Stochastic Optimization," Department of Mathematics, University of California at Davis, CA, 11 August 1996.

Brown, G., and Halwachs, T., "Combinatoric Optimization and its Application," Mathematics Symposium, National Security Agency, Ft. Meade, MD, 6 August 1996.

Bradley, G., "Panel Discussion on OR and the Web," IFORS 1996, Vancouver, British Columbia, Canada, 8-12 July 1996.

Wood, K., "Some Military Applications of Operations Research," Computer Science and Operations Research Department, North Dakota State University, Fargo, ND, 18 July 1996.

## PROJECT SUMMARIES

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Wood, K., and Morton, D., "Solving a Stochastic Network Capacity Expansion Problem," INFORMS National Meeting, Washington, DC, 7-10 May 1996.

Brown, G., Wood, K., and Dell, R., "Modeling for Solution Persistence," INFORMS National Meeting, Washington, DC, 7-10 May 1996.

Brown, G., and Halwachs, T., "Portable Optimization Toolkit," National Security Agency, Ft. Meade, MD, 6 May 1996.

Wood, K., and Morton, D., "Solving a Stochastic Network Capacity Expansion Problem," 5th CSTS Conference of Computer Science and Operations Research, Dallas, TX, 7-19 January 1996.

Wood, K., and Morton, D., "Stochastic Network Optimization," NSF Workshop on Stochastic Programming, University of Arizona, Tucson, AZ, 16-17 January 1996.

### THESES DIRECTED:

Adams, D., "A Heuristic Procedure to Aggregate Containers onto Pallets and Plan the Loading of Pallets into Trucks," Master's Thesis, Naval Postgraduate School, March 1996.

Dundas, J., "Optimal Fleet Modernization Model for the U.S. Navy's Combat Logistics Helicopter," Master's Thesis, Naval Postgraduate School, March 1996.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

**KEYWORDS:** Optimization, large-scale optimization, stochastic optimization

### CHAIR OF APPLIED SYSTEMS ANALYSIS

Ronald L. Brown, Military Instructor

Department of Operations Research

Sponsor: Chief of Naval Operations (N81)

**OBJECTIVE:** To provide a direct relationship between the Director, Assessment Division (N81) and the Superintendent of the Naval Postgraduate School and support activities designated in the joint Memorandum of Understanding between the Superintendent and N81.

**SUMMARY:** During the current year, funding was used for support of student and faculty travel required during thesis and research work, support of faculty course development and research, and support of hardware and software upgrades within the Operations Research Department.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** Operations research, modeling and simulation, curriculum development

## PROJECT SUMMARIES

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### PLANNING ACQUISITION OF THEATER MISSILE DEFENSE SYSTEMS

G.G. Brown, Professor

Robert F. Dell, Associate Professor

Department of Operations Research

Sponsor: Office of the Under Secretary of Defense, Defense Systems (Acquisition and Technology)

**OBJECTIVE:** Develop optimization models to help select funding profiles for theater ballistic missile defense and cruise missile defense systems.

**SUMMARY:** The investigators provided research, support, and development of optimization models tailored to resource allocation for acquisition of theater ballistic missile defense and cruise missile defense systems. The models can help identify the best method to provide desired systems given budget limitations through both years 2002 and 2010. Model design and implementation was completed in 1996.

#### CONFERENCE PRESENTATION:

Tarantino, W., Brown, G.G., and Dell, R.F., "Planning Acquisition of Theater Missile Defense Systems," National Meeting of the Institute for Operations Research and the Management Sciences, Washington, DC, 5-8 May 1996.

#### THESIS DIRECTED:

Carr, D.A., "Optimally Scheduling Theater Missile Defense Procurement," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Other (Optimization)

**KEYWORDS:** Capital budgeting, optimization, mixed linear integer programming application

### SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH, NATIONAL SECURITY AGENCY

G.G. Brown, Professor

Department of Operations Research

Sponsor: National Security Agency

**OBJECTIVE:** Provide on-call analytical support to the National Security Agency.

**SUMMARY:** Available only from sponsor.

#### CONFERENCE PRESENTATIONS:

Brown, G., and Halwachs, T., "Combinatoric Optimization and its Application," Mathematics Symposium, National Security Agency, Ft. Meade, MD, 6 August 1996.

Brown, G., and Halwachs, T., "Portable Optimization Toolkit," National Security Agency, Ft. Meade, MD, 6 May 1996.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

**KEYWORDS:** Optimization

## PROJECT SUMMARIES

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### OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT

Robert F. Dell, Associate Professor

Department of Operations Research

Sponsor: U.S. Army Base Realignment and Closure Office

**OBJECTIVE:** Develop optimization models to assist with installation management.

**SUMMARY:** The investigator is providing research, support, and development of optimization models to assist the Army's Base Realignment and Closure Office (BRACO). There are three modeling efforts at different levels of development in 1996: (1) continued refinement to BRACAS (Base Realignment and Closure Action Scheduler), an optimization model developed by the investigator and used extensively by BRACO; (2) initial development of an optimization model to assist with allocation of installation operating budgets; and (3) initial development of an optimization model to assist with allocation of environmental clean-up budgets.

**THESIS DIRECTED:**

Goette, H., "Budgeting for Environmental Clean-up of Army Bases," Master's Thesis in Operations Research, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Other (Optimization)

**KEYWORDS:** BRAC, capital budgeting, optimization, mixed linear integer programming application

### SCHEDULING ARMY BASE REALIGNMENT AND CLOSURE ACTIONS

Robert F. Dell, Associate Professor

Department of Operations Research

Sponsor: U.S. Army Base Realignment and Closure Office

**OBJECTIVE:** Develop optimization models for scheduling base realignment and closure actions.

**SUMMARY:** This research produced an integer linear programming model, BRACAS (Base Realignment and Closure Action Scheduler). BRACAS optimally schedules base realignment and closure (BRAC) actions (e.g., personnel realignments and construction schedules) in order to realize BRAC savings as soon as possible while satisfying yearly budget limits. During 1996 the investigator used BRACAS to assist the Army revise its implementation schedules for the 1995 BRAC actions.

**CONFERENCE PRESENTATIONS:**

Dell, R.F., Brown, G.G. and Wood, R.K., "Modeling for Solution Persistence," National Meeting of the Institute for Operations Research and the Management Sciences, Washington, DC, 5-8 May 1996.

Dell, R.F., "Optimizing Base Realignment and Closure Implementation," Optimization Days, Montreal, Canada, 13-15 May 1996.

**DoD KEY TECHNOLOGY AREAS:** Other (Optimization)

**KEYWORDS:** BRAC, optimization, mixed linear integer programming application



## PROJECT SUMMARIES

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### ANALYTICAL TOOL DEVELOPMENT FOR JOINT THEATER-LEVEL MODELS OF THE FUTURE

D.P. Gaver, Distinguished Professor  
S.H. Parry, Professor  
P.A. Jacobs, Professor  
M.A. Youngren, Military Instructor  
Department of Operations Research  
D.S. Davis, Associate Professor  
Department of Physics

Sponsor: The Joint Staff and the Naval Postgraduate School-Institute for Joint Warfare Analysis

**OBJECTIVE:** Purpose of the research is to adapt, extend and enhance capabilities of Future Theater Level Model Architecture to joint arenas. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems and data fusion.

**SUMMARY:** New models for sensors and the allocation of sensor effort have been formulated. The effect of various levels of sensor effort on combat has been and is being modeled in various scenarios.

#### PUBLICATION:

Gaver, D.P., and Jacobs, P.A., "Attrition Modeling with Decoys: An OOTW Motivation," Naval Postgraduate School Technical Report NPS-OR-96-011, accepted for publication in Naval Research Logistics.

#### CONFERENCE PRESENTATIONS:

Youngren, M.A., Gaver, D.P., Jacobs, P.A., and Parry, S.H., "Assessing the Impact of C3I on Joint Theater-Level Warfighting," 64th Military Operations Research Society Symposium, Fort Leavenworth, KS, 18-20 June 1996.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Combat Implications of Battlespace Awareness," INFORMS National Meeting, Atlanta, GA, 3-6 November 1996.

Gaver, D.P., Jacobs, P.A., Parry, S.H., and Youngren, M.A., "Joint Stochastic Warfare Analysis Research," Thirty-fifth U.S. Army Operations Research Symposium (AORS XXXV), Fort Lee, VA, 12-14 November 1996.

#### THESES DIRECTED:

Song, S-J., "Probability Models for Assessing the Value of Battle Damage Assessment in the Defense Against Sequential Theater Missile Attacks," Master's Thesis, Naval Postgraduate School, March 1996.

Munson, K.H., Jr., "Toward Assessment of Dominant Battlespace Awareness: A Remote Sensor System Model," Master's Thesis, Naval Postgraduate School, March 1996.

Martinez, E.R., "A Stochastic Simulation of a United States Conflict with a Land-based Opponent: The Impact of C<sup>4</sup>ISR," Master's Thesis, Naval Postgraduate School, September 1996.

Hume, R.S., "Modeling Attack Helicopter Operations in Theater Level Operations," Master's Thesis, Naval Postgraduate School, June 1996.

#### OTHER:

Yamauchi, H., "Stochwars," Simscript software, September 1996.

Youngren, M.A., "Stochastic-dynamic simulation model of deep-strike operations," Visual Basic software, December 1996.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Modeling and Simulation

**KEYWORDS:** Combat models, bayesian perception updating, decision analysis

### **DYNAMICAL, APPLIED PROBABILITY AND STATISTICAL MODELING IN OPERATIONAL, TOXICOLOGICAL AND ENVIRONMENTAL PROBLEMS**

**D.P. Gaver, Distinguished Professor**

**P.A. Jacobs, Professor**

**Department of Operations Research**

**Sponsor: Naval Medical Research Institute, Toxicology Detachment  
and the Naval Postgraduate School**

**OBJECTIVE:** To conduct mathematical research in applied probability modeling and evaluation, e.g. of quantitative toxicology. The models usefully supplement, or even replace, certain large-scale time-consuming simulations. They have implications for joint operational situations.

**SUMMARY:** Models of organic cell response to toxins have been proposed and assessed using experimental results. Models for allocation of jobs to unequally-capable processors have been proposed and studied. Models for studying the allocation of units to destructive testing when the total number of units is fixed have been developed and studied.

#### **PUBLICATIONS:**

Gaver, D.P., and Jacobs, P.A., "Waiting Times when Service Times Are Stable Laws: Tamed and Wild," Naval Postgraduate School Technical Report NPS-OR-96-009.

Gaver, D.P., Jacobs, P.A., Becker, K., and Lawphongpanich, S., "Allocation of Jobs to Unequally-capable Processors: A Planning Approach," Naval Postgraduate School Technical Report NPS-OR-96-010.

#### **CONFERENCE PRESENTATIONS:**

Carpenter, R.L., Gaver, D.P., Narayanan, T.K., Jacobs, P.A., and Jung, A., "A Stochastic Model of Cell Toxicity: Comparison with Cell Culture Results," Poster Session: Liver/Gastrointestinal System, 35th Annual Meeting of the Society of Toxicology, Anaheim, CA, 10-14 March 1996.

Gaver, D.P. and Jacobs, P.A., "Queuing with Tamed Stable Law Service," INFORMS National Meeting, Washington, DC., 5-8 May 1996.

Gaver, D.P. and Jacobs, P.A., "Testing for and Removing Design Faults: A Missile Example," Joint Statistical Meetings, Chicago, IL, 4-8 August 1996.

Gaver, D.P. and Jacobs, P.A., "Two Biological Service Problems," INFORMS National meeting, Atlanta, GA, 3-6 November 1996.

#### **OTHER:**

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., and Burkhart, J.G., "A Mathematical Model for Intra-cellular Effects of Toxins on DNA Adduction and Repair," Bulletin of Mathematical Biology, 59, (1997) pp. 89-106.

Gaver, D.P. and Jacobs, P.A., "Waiting Times when Service Times Are Stable Laws: Tamed and Wild," Accepted for publication in Recent Contributions in Applied Probability and Stochastic Processes.

## PROJECT SUMMARIES

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Gaver, D.P., Jacobs, P.A., and Dudenhoeffer, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," Proceedings of the Seventh International Symposium on Applied Stochastic Models and Data Analysis, pp 201-210. To appear in Wiley volume of conference proceedings tentatively titled From Models to Data Mining: Aspects of the Modelling Process, edited by J. Janssen and S. McClean.

Verhaar, H.J.M., Morroni, J.S., Reardon, K.F., Hays, S.M., Gaver, D.P., Carpenter, R.L., and Yang, R.S.H., "A Proposed Approach to Study the Toxicology of Complex Mixtures of Petroleum Products: The Integrated Use of QSAR, Lumping Analysis and PBPK/PD Modeling," forthcoming in Environmental Health Perspectives, Vol. 105, Supplement 1, January 1997.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Environmental Quality

**KEYWORDS:** Stochastic models, dose-response models, biological cells, toxic chemicals, bioassay, operational testing, allocation of scarce resources

### MODEL SUPPORT FOR CRUSADER OPERATIONAL EVALUATION

D.P. Gaver, Distinguished Professor

P.A. Jacobs, Professor

Department of Operations Research

Sponsor: U.S. Army Training and Doctrine Analysis Command

**OBJECTIVE:** To develop top-level models that support parametric sensitivity analysis of suitable Measures of Effectiveness (MOEs) for Army forces equipped with the Crusader.

**SUMMARY:** Probabilistic models have been developed that relate engineering parameters to operational effectiveness.

#### THESIS DIRECTED:

Duke, J.R., "A Markov Model for Parametric Sensitivity Analysis of Crusader Effectiveness," Master's Thesis, Naval Postgraduate School, June 1996.

#### OTHER:

Duke, J.R., "Microsoft Visual Basic Program with Microsoft Excel V7.0," Spreadsheet user interface, June 1996.

Uribe, L., "Crusader V1.0," software, December 1996.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Modeling and Simulation

**KEYWORDS:** Probability models, combat models

### QUANTITATIVE TOXICOLOGY

D.P. Gaver, Distinguished Professor

P.A. Jacobs, Professor

Department of Operations Research

Sponsor: U.S. Army Biomedical Research and Development Laboratory

**OBJECTIVE:** To initiate an effort to provide quantitative, data-based assessments of toxicological phenomena relevant to Army goals and to advance the quantitative methodology needed for the assessments.

## PROJECT SUMMARIES

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**SUMMARY:** Statistical analyses of data from histopathologic examination of Japanese Medaka from health screens have been performed. The analyses indicate unexplained variation between the health screens. This unexplained variability may indicate compromised health in the fish. An analysis of data from a pathology report, an interim sacrifice for a field experiment using Japanese Medaka, has also been performed.

**PUBLICATION:**

Gaver, D.P., and Jacobs, P.A., "Research in Quantitative Bioassay Methodology and Risk Analysis and Characterization," Naval Postgraduate School Technical Report NPS-OR-96-008.

**DoD KEY TECHNOLOGY AREAS:** Environmental Quality, Human Systems Interface

**KEYWORDS:** Combining information, data analysis of bioassay data, generalized linear regression, analysis of variance, missing data

### NITE HAWK SENSOR FUSION DEMONSTRATION

William K. Krebs, Assistant Professor

Department of Operations Research

Sponsor: Naval Medical Research Development Command and  
Assistant Secretary of the Navy, Office of Safety and Survivability

**OBJECTIVE:** The Naval Postgraduate School, Naval Research Laboratory, Lockheed Martin Corporation, and NASA Dryden demonstrated a color night vision sensor (registering a 1st Generation FLIR and an image intensifier (I2) display into a single image) on a F/A-18 NITE Hawk targeting FLIR pod. Our primary objective was demonstrate that sensor fusion was significantly better for target recognition compared to the existing NITE Hawk targeting pod. This new capability has the potential to improve target search and acquisition thus allowing for increased standoff ranges.

**SUMMARY:** The project demonstrated a color sensor fusion system which was housed inside a F/A-18 NITE Hawk targeting FLIR pod. The system produced an enhanced targeting capability that may significantly increase aerial stand-off ranges by improving target search and acquisition. NPS data from fleet aviators performing laboratory-based tasks showed that target recognition and situational awareness was improved when the target images were enhanced by color from two separate, but fused spectral bands. In May and July 1996, the pod was flown on NASA Dryden's F/A-18 and got results consistent with our laboratory findings. These two flights were flown over NAS China Lake's weapon range and surrounding areas. Specifically, the data consisted of multiple military targets, surrounding urban areas, High Sierra's, and desert terrain. The success of the two flights has enabled increased military sponsorship for several more flights in FY97. The goal of FY97 flights will be to test several combinations of low-light, short wave IR, mid wave IR, and long wave IR sensors within the NITE Hawk pod. In particular, what combination of bands will improve standoff ranges compared to the single 1st Gen FLIR band. If successful, the system could be fitted into platforms such as LANTIRN, NITE Hawk, and ground based vehicles.

**CONFERENCE PRESENTATION:**

Krebs, W.K., Scribner, D.A., Schuler, J., Miller, G., and Lobik, D., "Human Factor Test and Evaluation of a Low Light Sensor Fusion Device for Automobile Applications," Automotive Night Vision/Enhanced Driving Conference, Detroit, MI, 1996.

**DoD KEY TECHNOLOGY AREAS:** Biomedical, Electronics, Sensors, Air Vehicles

**KEYWORDS:** Sensor fusion, FLIR, night vision devices, target, pod

## PROJECT SUMMARIES

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### NITE HAWK SENSOR FUSION DEMONSTRATION FLIGHT SUPPORT

William K. Krebs, Assistant Professor

Department of Operations Research

Sponsor: Naval Research Laboratory

**OBJECTIVE:** The main focus of the effort will be to make a series of test flights with the modified NITE Hawk pod on the F-18 and then analyze the data in terms of both sensor performance and visual performance testing. The project team consisted of the Naval Postgraduate School, Naval Research Laboratory, Lockheed Martin Corporation, and NASA Dryden. The flights will be conducted at different times of the night under different environmental conditions, primarily various background temperatures and light levels. The image sequences obtained will be of assorted natural terrains and urban settings with some military targets present. The final data product will be archival CD-ROMs from the flights for data analysis purposes, as well as the creation of MPEG files based on long image sequences for visual psycho-physical testing at NPS. Each CD-ROM will contain about a one minute sequence of fused color imagery.

**SUMMARY:** Fusing low-light-level sensor imagery with FLIR imagery, into a single color output display is a topic under consideration by the Navy. This fusion system will quantify the degree to which a FLIR/LL color fusion system will improve situational awareness and standoff range for Navy and Marine Corps pilots operating rotary or fixed wing aircraft. This study will provide important inputs to the Advanced Technology Demonstration (ATD) "Color Night Vision System" scheduled to start in FY97. The Navy requirements officer needs this input data to assess the degree to which the proposed sensor configuration will meet future Navy needs. The proposed FY96 effort will utilize off-the-shelf components and existing Navy assets to demonstrate the system concept in a NITE Hawk pod flying on a laboratory F-18 aircraft - no components need be developed to acquire high quality imagery down to starlight illumination levels. In fact for a pod mounted configuration there may be no requirement for a LLCCD at all, as a Gen III intensified CCD with a 25mm tube, and extended wavelength response may already perform at a level that could never be achieved with the LLCCD approach described in the ATD.

Our flight data demonstrated that sensor fusion could be achieved on an operational aircraft for minimal cost. In particular, the results demonstrated that there was a strong sensor by scene interaction. Accordingly, further flights will be flown in FY97 to evaluate the efficiency and effectiveness of various combinations of low-light, short wave IR, mid wave IR, and long wave IR for target recognition and situational awareness.

**DoD KEY TECHNOLOGY AREAS:** Biomedical, Electronics, Sensors, Air Vehicles

**KEYWORDS:** Sensor fusion, FLIR, night vision devices, target, pod

### SENSOR FUSION EVALUATION OF NIGHT-TIME SCENES

William K. Krebs, Assistant Professor

Department of Operations Research

Sponsor: Office of Naval Research

**OBJECTIVE:** The intent of this FY96 study is to quantitatively assess the impact of the next generation of NVD on human performance. More specifically, two studies, Static Display and Dynamic Display, will assess the impact of fusing an I<sup>2</sup>CCD and 2<sup>nd</sup> Gen FLIR into a single color or non color output display and compare its performance to a single I<sup>2</sup>CCD or 2<sup>nd</sup> Gen monochrome output display. Experimental stimuli will consist of previously collected NVD data obtained from the Army Night Vision Lab, Ft. Belvoir, Virginia. Lastly, alternative algorithms will be assessed and developed to determine the best characteristics for optimal sensor fusion.

**SUMMARY:** a) NPS: Seventeen military aviators participated in a paired comparison task to determine if sensor fusion (MITLL monochrome, MITLL color, and NRL color) was significantly better than each of the single bands (I<sup>2</sup>CCD or 2<sup>nd</sup> Gen FLIR). At the beginning of each trial, a fixation cross was displayed on the center of the screen for 200 msec followed by the presentation of the first stimulus interval (3 sec), an ISI of 100 msec, the second stimulus interval (3 sec). Subjects were required to respond what image was best, depending upon the question, between the two

## PROJECT SUMMARIES

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images. Subjects preferred color (NRL and MITLL color) best followed by FLIR, MITLL monochrome fusion, and PCCD.

b) UC Berkeley: Several algorithms for such sensor fusion have been suggested in the past. These algorithms suffer from the drawback of being computationally too intensive. Hence any real-time implementation would require a tremendous amount of hardware. In this article we propose a novel analog VLSI realizable algorithm for fusion of visible and thermal imagery. The proposed method offers the combined advantages of being faster than the previous methods by several orders of magnitude, as well as requiring considerably less hardware and power consumption. The sensory inputs of our algorithm requires two separate bands of thermal and visible imagery. A method of evaluating the advantages gained by such image fusion algorithms have been developed. This method is based on the frequency response characteristics of the images. A Human Contrast Sensitivity function model was also implemented for the purpose.

### CONFERENCE PRESENTATION:

Sampson, M.T., Krebs, W.K., Scribner, D.A., and Essock, E.A., "Visual Search in Natural (Visible, Infrared, and Fused Visible and Infrared) Stimuli," Investigative Ophthalmology and Visual Science, (SUPPL) 36, 1362, Fort Lauderdale, FL, 1996.

### THESIS DIRECTED:

Sampson, M.T., "An Assessment of the Impact of Fused Monochrome and Fused Color Night Vision Displays on Reaction Time and Accuracy in Target Detection," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Biomedical, Human Systems Interface, Sensors

**KEYWORDS:** Sensor Fusion, target recognition, FLIR, night vision devices

### OPTIMAL DELAY ENTRY PROGRAM PLACEMENT POLICY

Siriphong Lawphongpanich, Associate Professor

Department of Operations Research

Sponsor: Navy Recruiting Command

**OBJECTIVE:** Prior to the beginning of each fiscal year, the Navy Recruiting Command must determine how many candidates to recruit in each month. If agreed and qualified, these candidates or recruits sign a contract to enlist into the Navy and are generally placed in the Delay Entry Program (DEP) while waiting to enter basic training. The time spent in the DEP varies depending on each recruit's qualification and background as well as his or her rating. Attritions from the DEP are expensive and occur regularly. The main goal of this project is to develop a technique for: (i) determining the appropriate number of candidates to recruit in each month, and (ii) placing them into the DEP so as to minimize the cost of recruiting.

**SUMMARY:** The problem of determining the number of candidates to recruit monthly (referred to as the new contract objective or NCO) and their placement in the DEP was formulated as a nonlinear program. The program's objective is to minimize to cost of expected DEP attritions and the needed manpower. The program also ensures that operating constraints are observed. For example, the numbers of new contracts in each month must be sufficient to meet the monthly goals set by the Naval Bureau of Personnel. In placing the contracts in the DEP, they should be distributed so as to avoid having a large proportion of new contracts entering basic training in a single month or leaving them in the DEP for too long. Numerous studies show that the likelihood of attrition increases with the time spent in the DEP.

The preliminary version program was implemented in MS Excel with Visual Basic for Applications. Program inputs are entered via dialog boxes. Macros for reoptimization, printing, and displaying results were provided. Final version of the program is being prepared.

## PROJECT SUMMARIES

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### THESIS DIRECTED:

Simpson, P.G., "Optimal DEP Placement Policy," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software

**KEYWORDS:** Optimization, attrition, military recruiting

### JOINT DUTY ASSIGNMENT LIST SUPPORTABILITY MODEL

Paul R. Milch, Professor  
Department of Operations Research  
Sponsor: Naval Postgraduate School

**OBJECTIVE:** The goal of this effort is to analyze the joint education and training track of joint specialty officers (JSO's) in order to forecast the future supply of available JSO's.

**SUMMARY:** The Naval Aviation Community was selected to analyze the education and training process of JSO's. Two separate training paths to JSO eligibility were considered. The most preferred path is sending officers through the Joint Professional Military Education (JPME) first and then placing them in billets designated for joint duty. An alternative path allows officers to complete this sequence in the reverse order. Most often the two assignments are not consecutive to each other. A spreadsheet model was constructed forecasting within the Aviation Community the number of JSO eligible officers by rank. When the forecast was compared to actual data (over the FY1991-95 period) it was found to be highly accurate in forecasting the total number of JSO eligible officers with less success obtained by rank.

### THESIS DIRECTED:

Lineberry, R.G., "Joint Officer Supportability Model: Joint Education and Training of U.S. Navy Aviators," Master's Thesis, Naval Postgraduate School, March 1996

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Manpower, Personnel and Training

**KEYWORDS:** Joint service, joint duty, joint specialty

### USE OF A COMPUTER AIDED EXERCISE TO EVALUATE CINC STAFF TRAINING BASED ON THE UNIVERSAL JOINT TASK LIST

Sam H. Parry, Professor  
Department of Operations Research  
Sponsor: Defense Manpower Data Center

**OBJECTIVE:** This continuing research effort developed measures of effectiveness for tasks in the Universal Joint Task List (UJTL) related to several functional areas. The primary emphasis was to provide the staff planner with an ability to associate causal reasons for critical events in an actual CINC exercise using actual runs from the Joint Theater Level Simulation (JTLS).

**SUMMARY:** The UJTL, a supplement to the Joint Training Manual, is a comprehensive listing of all joint tasks pertaining to the Armed Forces of the United States. Tasks are defined as they relate to the strategic, operational, and tactical levels of war. This research, initiated in October, 1994, developed an exercise analysis methodology for evaluating CINC staff performance in the execution of joint tasks during the conduct of a Computer Aided Exercise (CAX). Five different JTLS theater conflicts were run to provide the data base for analysis. Causal reasons were developed for critical events which occurred in six functional areas: ground maneuver forces, protection of high value assets (both

## PROJECT SUMMARIES

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land and sea based), prosecution of enemy high value targets, amphibious operations, and force deployment. This research continues in FY97.

### CONFERENCE PRESENTATIONS:

Parry, S., "Use of a Computer Aided Exercise to Evaluate CINC Staff Training Based on the UJTL," 64th Military Operations Research Symposium, Fort Leavenworth, KS, 18-20 June 1996.

Parry, S., "Causal Reasons for Significant Events in a Computer Aided Exercise," Joint Readiness Steering Group Conference, The Pentagon, Washington, DC, 24 October 1996.

### THESES DIRECTED:

Brown, K., "Evaluating Operational Maneuver in a Computer Aided Exercise," Master's Thesis, Naval Postgraduate School, September 1996.

Cwick, M., "Analyzing Amphibious Logistics Capabilities in the Joint Theater Level Simulation (JTLS)," Master's Thesis, Naval Postgraduate School, September 1996.

Gordon, K., "A Methodology for Evaluating Operational Firepower During a Computer Aided Exercise," Master's Thesis, Naval Postgraduate School, September 1996.

Mustin, J., "Evaluating Carrier Battlegroup Anti-Air Warfare Capability in a Computer Aided Exercise," Master's Thesis, Naval Postgraduate School, September 1996.

Sullivan, M., "A Methodology for Evaluating a Joint Mobilization Plan Using the Joint Theater Level Simulation (JTLS)," Master's Thesis, Naval Postgraduate School, September 1996.

Thurman, J., "A Methodology for Evaluating Force Protection During a Computer Aided Exercise," Master's Thesis, Naval Postgraduate School, September 1996.

### OTHER:

Briefings were given to Mr. Lou Finch, Deputy Under Secretary of Defense - Readiness, who is the DoD Sponsor of this effort through the Defense Manpower Data Center.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software

**KEYWORDS:** Joint missions, measures, training evaluation

### OPTIMIZATION MODELING FOR AIRLIFT MOBILITY

Richard E. Rosenthal, Professor

Department of Operations Research

Sponsor: U.S. Air Force Studies and Analyses Agency

**OBJECTIVE:** The objective of this multi-year research project is to help the Air Force improve the efficiency of airlift mobility through optimization modeling technology.

**SUMMARY:** A multi-period optimization model, implemented in GAMS, has been developed to determine the maximum on-time throughput of air cargo and passengers that can be transported with a given fleet over a given network, subject to appropriate physical and policy constraints. The model has been delivered to the Air Force Studies and Analyses Agency, which has used it to help answer questions about selecting airlift assets and about investing or



## PROJECT SUMMARIES

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divesting in airfield infrastructure. NPS faculty and students, along with colleagues at the University of Texas at Austin and at RAND, worked closely with the Air Force on very large-scale versions of the model.

### PUBLICATIONS:

Morton, D.P., Rosenthal, R.E., and Teo-Weng, Lim, "Optimization Modeling for Airlift Mobility," Military Operations Research, Vol. 1, No. 4, 49-68, Winter, 1996.

Rosenthal, R.E., Morton, D.P., Baker, S.F., Teo-Weng, Lim, Fuller, D.F., Goggins, D., Toy, A.O., Turker, Y., Horton, D.B., and Briand, D., "Application and Extension of the *THRUPUT II* Optimization Model for Airlift Mobility," 31pp., Technical Report NPS-OR-018, Operations Research Department, Naval Postgraduate School, Monterey, CA (1996). [submitted to Military Operations Research].

### CONFERENCE PRESENTATIONS:

Rosenthal, R.E., Morton, D.P., Baker, S.F., Teo-Weng, Lim, Fuller, D.F., Goggins, D., Toy, A.O., Turker, Y., Horton, D.B., and Briand, D., "Application and Extension of the *THRUPUT II* Optimization Model for Airlift Mobility," 64th Military Operations Research Society Symposium, U.S. Army Command and General Staff College, Ft. Leavenworth, KS, June 1996.

Rosenthal, R.E., Morton, D.P., Baker, S.F., and Melody, L., "The NPS/RAND Mobility Optimizer (NRMO)," Fifth Mobility Modeling and Simulation Users Group Meeting, Naval Postgraduate School, Monterey, CA, August 1996.

### THESES DIRECTED:

Toy, A.O., "Route Prioritization for an Airlift Mobility Optimization Model," Master's Thesis in Operations Research, September 1996.

Fuller, D.F., II, "Reduction of a Large-Scale Global Mobility Optimization Model Through Aggregation," Master's Thesis, Naval Postgraduate School, December 1996.

**DoD KEY TECHNOLOGY AREAS:** Other (Optimization; mathematical modeling)

**KEYWORDS:** Optimization, applications, airlift mobility, logistics

## BAYESIAN CALCULUS FOR MINEFIELDS

Alan Washburn, Professor  
Department of Operations Research  
Sponsor: Office of Naval Research

**OBJECTIVE:** The number and type of mines present in a minefield is typically only very roughly known at the beginning of a clearance operation, and must therefore be represented stochastically. Therefore develop Bayesian methods for estimating the numbers of various types of mines in a minefield, and for revising those estimates based on experience in minefield clearance. Also incorporate the methods into MIXER, a prototype Bayesian tactical decision aid for minefield clearance.

**SUMMARY:** The Katz distribution is introduced as a natural prior distribution for mine numbers, since this two-parameter class of distributions is preserved under the sample-and-subtract operation that minefield clearance amounts to, statistically speaking. Various properties of Katz distribution are derived. MIXER, which is based on Katz distributions for each of several mine populations, is extended to include a facility for optimizing a clearance plan, subject to a constraint on the time available for clearance.

## PROJECT SUMMARIES

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### **PUBLICATION:**

Washburn, A., "Katz Distributions, with Applications to Minefield Clearance," Naval Postgraduate School Technical Report NPS-OR-96-003, March 1996.

### **THESIS DIRECTED:**

Romberger, D., "Optimization Methods for Mixed Minefield Clearance," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface

**KEYWORDS:** Bayes, minefield

### **STOCHASTIC DRIFT MODEL**

Alan Washburn, Professor

Department of Operations Research

Sponsor: U.S. Coast Guard

**OBJECTIVE:** Add stochastic features to the iceberg drift model used by the International Ice Patrol. Icebergs are subject to several influences that are not exactly predictable. A stochastic representation of these features will permit an estimate of forecast uncertainties for the location, type, and number of icebergs that threaten shipping.

**SUMMARY:** Two stochastic features have been added. One is the effect of iceberg splitting. Splitting tends to accelerate disintegration, and, in the process, produce smaller iceberg "children" that behave differently from the parents. The other feature is the effect of warm and cold-core Gulf Stream eddies, which can produce strong but erratic effects on iceberg drift. Both features are represented as Monte Carlo effects in the NPS version of the IIP drift model. A theoretical study of the long term effect of splitting on the distribution of iceberg size is also undertaken.

### **PUBLICATION:**

Washburn, A., "Stochastic Features in ICEBERG," Naval Postgraduate School Technical Report NPS-OR-96-017PR, December 1996.

**DoD KEY TECHNOLOGY AREAS:** Other

**KEYWORDS:** Ice, iceberg

### **AIRCRAFT ENGINE PERFORMANCE IMPROVEMENT**

W.M. Woods, Professor

Department of Operations Research

Sponsor: Naval Air Systems Command

**OBJECTIVE:** Develop optimal no-build times relative to hard inspection times for critical components of fielded TF34 aircraft engines.

**SUMMARY:** Repair of a critical component in an aircraft engine can be performed for cost  $C_1$  when the engine is off the wing (now) under repair due to a failure that does not involve the critical component which has hard inspection time  $T$  and current accumulated test time,  $X$ . If not repaired now the critical component can be repaired at next engine failure if it occurs before total operating time  $T$  has accumulated on the critical component (again for cost  $C_1$ ) or cost  $C_2$  if total operating time accumulates to  $T$  before the next engine failure. If the critical component fails before the next engine

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failure due to other reasons, the repair cost of the critical component is  $C_3$ . The no-build time,  $X_0$ , is minimum value of accumulated time,  $X$ , on the critical component for which repair on the critical component should occur when the engine is off the wing due to failure for reasons other than the critical component. The optimal no-build time,  $X_0$ , is the value of  $X_0$  which makes the expected repair cost per operating hour when repair is down (now) equal to the expected repair cost per hour when the decision is made to wait for the next failure. Expected repair cost per operating hour is computed assuming Weibull failure time probability distributions for the engine and the critical component using TF34 engine failure data from the NALDA data base. An integral equation was developed that can be solved to determine the optimal no-build time  $X_0$ .  $X_0$  depends on the parameters of the two Weibull distributions and the two ratios  $C_2/C_1$  and  $C_3/C_1$ . Graphs are provided that show how  $X_0$  changes as these two ratios change.

**DoD KEY TECHNOLOGY AREAS:** Other (System Effectiveness)

**KEYWORDS:** Optimal maintenance, system effectiveness

### SHIP MISSILE DEFENSE EFFECTIVENESS

W.M. Woods, Professor

Department of Operations Research

Sponsor: Naval Warfare Assessment Center

**OBJECTIVE:** Develop a probabilistic system effectiveness equation that can be used to compute the probability that an Exocet missile will not hit a DD-963 Spruance Class Destroyer given ship configuration, weapons firing policy, weapons systems availabilities, and weapons system conditional kill probabilities given crew readiness state and Exocet detection range.

**SUMMARY:** The probability that a DD-963 Spruance Class Destroyer can kill an incoming Exocet missile depends on the capabilities of 22 subsystems including the Nato Seasparrow Missile System, the MK45 guns, the Chaff, the CWIS, and the MK23 TAS Radar. It also depends on the crew readiness state, the range of the Exocet when detected, the firing policy of these systems, and the availability of the critical subsystems; e.g., TAS. An equation for computing this kill probability was developed and an Excel spreadsheet developed for performing the computations given the parameter values in the equation.

**DoD KEY TECHNOLOGY AREAS:** Other (System Effectiveness)

**KEYWORDS:** Missile defense effectiveness, system effectiveness

## PUBLICATIONS/PRESENTATIONS

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### JOURNAL PAPERS

- Brown, G.G., Dell, R.F., and Farmer, R.A., "Scheduling Coast Guard District Cutters," Interfaces, Vol. 26, pp. 59-72, 1996.
- Chavez, F.P., Service, S.K., and Buttrey, S.E., "Temperature-Nitrate Relationships in the Central and Eastern Tropical Pacific," Journal of Geophysical Research, Vol. 101 No. 9, pp. 20,553-20,563, 1996.
- Dell, R.F., Batta, R., and Karwan, M.H., "The Multiple Vehicle TSP with Time Windows and Equity Constraints Over a Multiple Day Horizon," Transportation Science, Vol. 30, pp. 120-133, 1996.
- Dell, R.F., Eagle, J.N., Martins, G.H.A., and Santos, A.G., "Solving Constrained Path, Moving-Target Search Problems Using Multiple Searchers," Naval Research Logistics, Vol. 43, pp. 463-480, 1996.
- Dell, R., Farmer, R., and Brown, G., "Scheduling Coast Guard District Cutters," Interfaces, 26, March-April 1996, pp. 59-72.
- Essock, E.A., Fechtner, R.D., Zimmerman, T.J., Krebs, W.K., and Nussdorf, J.D., "Binocular Function in Early Glaucoma," Journal of Glaucoma, (5), 395-405, 1996.
- Morton, D.P., Rosenthal, R.E., and Lim Teo-Weng, "Optimization Modeling for Airlift Mobility," Military Operations Research, Vol. 1, No. 4, 49-68, Winter, 1996.
- Washburn, A., "The Operations Analysis Curriculum at the Naval Postgraduate School," Interfaces 26, 71-80, September, 1996.
- Dell, R., Farmer, R., and Brown, G., "Scheduling Coast Guard District Cutters," Interfaces, 26, March-April 1996, pp. 59-72.

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## 1996 THESIS ABSTRACTS

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### **A HEURISTIC PROCEDURE TO AGGREGATE CONTAINERS ONTO PALLETS AND PLAN THE LOADING OF PALLETS INTO TRUCKS**

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**B.A., Virginia Military Institute, 1984**

**M.B.A., Troy State University, 1992**

**Master of Science in Operations Research-March 1996**

**Advisor: Gerald G. Brown, Department of Operations Research**

A heuristic procedure is presented which aggregates containers of multiple products onto pallets and then plans the loading of these pallets into trucks. The efficient loading of products onto pallets and pallets into trucks is an economic fundamental. In 1993 the value of products shipped by truck in the United States exceeded 4.6 trillion dollars or about 75.6 percent of gross domestic product. Industry sources estimate that 98% of all manufactured products are transported on pallets. The heuristic provides feasible solutions to the pallet and truck loading problem in real time. The method considers "real-world" criteria new to the literature, such as stacking compatibility among product containers and axle weight limits for trailers. The procedure is demonstrated with actual examples from the Defense Logistic Agency (DLA) and a commercial company.

### **HELMET MOUNTED DISPLAY SYMBOLOGY FOR NIGHT AIRBORNE MINE COUNTERMEASURES IN THE MH-53E HELICOPTER**

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**Master of Science in Aeronautical Engineering-December 1995**

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This study begins the process of developing and refining helmet mounted display (HMD) symbology appropriate for use by MH-53E helicopter pilots conducting night airborne mine countermeasures (AMCM) operations. The Navy is considering use of the Army Navy/Aviator Vision System (AN/AVS-7) HMD in the MH-53E to achieve a viable night AMCM capability. Needed is an initial design of appropriate night AMCM symbols to display on such an HMD system. Two new symbology elements critical to the tow segment of AMCM flight were designed and integrated into a preliminary HMD tow format for the MH-53E: tow boom skew angle and turn rate indicators. A fixed-based flight simulator was developed to evaluate the two proposed symbology elements. Seven fleet-experienced AMCM pilots qualified in the MH-53E flew simulated tow patterns while using the display to try to maintain AMCM tow parameters within specified limits. Both pilot performance data and subjective questionnaire results were collected and analyzed. Participants considered the proposed display easy to comprehend and use, and reported that such a display would be useful for night AMCM operations. Based on correlating performance and subjective data results, modifications to the evaluated tow symbology are recommended and a revised AMCM tow format is proposed.

### **GENERALIZED OPTIMIZED MODELING FOR DEFENSE CAPITAL PLANNING AND EQUIPMENT REPLACEMENT**

**Gregorio Ameyugo-Lieutenant Commander, Spanish Navy**

**Master of Science in Operations Research-September 1996**

**Advisor: Gordon H. Bradley, Department of Operations Research**

**Second Reader: Gerald G. Brown, Department of Operations Research**

Recurring issues for Navy and DoD analyst are decisions on the upgrade, purchase, and retirement of equipment with high capital cost and long useful life. Since the PHOENIX model was developed in the late eighties a number of these addressing different equipment procurement and modernization problems have been written at the Naval Postgraduate School. Those models have a common thread of purpose, data, and methods that suggest the possibility of building a common model subsuming those previous efforts.



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The model developed is a mixed-integer linear program written in GAMS, and its most appealing characteristic is the spreadsheet application that allows the user to enter data, solve the model, analyze its output, enter user feedback in the process of finding a new solution, and also to manage a collection of candidate solutions.

With this approach difficulties are hidden from the user who interacts only with the spreadsheet and does not have to build his own model. The combination of a generic model and the visual programming capability of Excel provides the user with a tool to accomplish more complete, complex and sophisticated analysis.

### **THE EFFECT OF GENDER ON ATTRITION AT THE DEFENSE LANGUAGE INSTITUTE FOREIGN LANGUAGE CENTER**

**George T. Arthur-Lieutenant, United States Navy  
B.S., United States Naval Academy, 1986**

**Master of Science in Operations Research-September 1996**

**Advisor: Lyn R. Whitaker, Department of Operations Research**

**Second Reader: Stephen M. Payne, Defense Language Institute**

The Defense language Institute Foreign Language Center (DLIFLC), located at the Presidio of Monterey, California, provides language training for Department of Defense military and civilian personnel. The Institute trains approximately 2,500 students annually, of which approximately 26 percent are female. Student attrition is a costly feature of this training program. Females experience roughly a 7 percent higher rate of attrition than males at DLIFLC. The Institute is interested in knowing whether this difference indicates a gender bias, or whether it can be explained by other factors. This study investigates this question. Specifically, data on FY-95 DLIFLC students are examined to determine factors which have a significant impact on attrition, with particular emphasis on the effects of gender. Such information is useful to the Institute for internal quality assurance efforts as well as part of potential cost saving measures.

### **A METHODOLOGY FOR UPDATING THE NAVY'S LOGISTICS FACTORS FILE**

**Raymond John Benedict-Lieutenant, United States Navy  
B.S., United States Naval Academy, 1989**

**Master of Science in Operations Research-June 1996**

**Advisor: Robert Read, Department of Operations Research**

**Second Reader: Dan Boger, Department of Systems Management**

This thesis develops a methodology for updating the Navy's Logistics Factors File, which has been neglected in recent years and requires updating. This study is limited to Repair Parts (Class IX of the Department of Defense Supply Class Codes) for the following four classes of ships: CVN-68 (Nimitz class) Aircraft Carriers, CG-47 (Ticonderoga class) Guided Missile Cruisers, DD-963 (Spruance class) Destroyers, and FFG-7 (Oliver Hazard Perry class) Guided Missile Frigates.

The current Logistics Factors File structure includes a single data entry in pounds per unit per day to describe the sustainment requirements of these units for all of the supply classes and their respective subclasses. For Repair Parts, these values are severely understated when compared to contemporary data. These "pounds per unit per day" random variables have heavily skewed distributions. These distributions can be fitted with mixtures of standard probability distributions, and it seems wise to recommend that associated variability information be included either directly in the Logistics Factors File, or in a readily available companion source.

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### **OPTIMIZING THE MODERNIZATION OF EASTERN EUROPEAN FORCES**

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**B.S., United States Naval Academy, 1988**

**Master of Science in Operations Research-March 1996**

**Advisor: Robert F. Dell, Department of Operations Research**

Many Eastern European countries desire a method to evaluate the capability and cost of their military forces. In 1995 the Program Analysis and Evaluation branch of the Office of the Secretary of Defense (OSD PA&E) provided a solution: the Defense Resources Management Model (DRMM). The DRMM is a database system that contains detailed report writing, allowing a nation's military to be described by: how its forces are organized and equipped; how it staffs its forces; how it scales its peacetime training rates; and how it practices budgeting and accounting. We present a multi-objective linear program extension to the DRMM that suggests optimal yearly unit levels, activity, manning, equipment, and war reserve materiel levels. Two objectives are used in the analysis: (1) We find the minimum budget required to maintain a given capability level, and (2) We find the maximum capability within an annual budget. Possible uses of the linear programming extension are demonstrated using a hypothetical but realistic Eastern European force supplied by OSD PA&E. Results show the ability to maintain current capability but reduce annual spending by up to 30 percent. Other results show how capability can be increased nearly 50 percent over a five-year time horizon by increasing annual budget levels ten percent above their current levels.

### **EVALUATING OPERATIONAL MANEUVER IN A COMPUTER-AIDED EXERCISE**

**Kevin Peter Brown-Captain, United States Army**

**B.S., United States Military Academy, 1987**

**Master of Science in Operations Research-September 1996**

**Advisor: Sam Parry, Department of Operations Research**

**Second Reader: George Connor, Department of Operations Research**

The development of proficient Joint Staffs at the Joint Task Force level is receiving increased emphasis. One of the primary training tools available is the use of computer-aided exercises. In utilizing these devices for training Joint Task Force Staffs, many observations can be made over the course of the exercise which aid in assessing readiness. The primary document used to focus the training and assessment effort is the Universal Joint Task List. The list provides both the staff and evaluators with a common document outlining critical events and activities which require successful accomplishment. The document is organized in a manner which defines activities associated with the many functional areas of staff activity including logistics, intelligence, force protection, and operational firepower planning.

It is the purpose of this thesis to provide a methodology for objectively assessing the staff's ability to conduct operational maneuver. Experimental runs using the Joint Theater Level Simulation demonstrate how critical events and command control decisions affect the tempo of battle and produce data elements which are useful in developing measures of performance for operational maneuver.

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### **TRADEOFF ANALYSIS MODEL FOR ARSENAL SHIP SURVIVABILITY AND SUSTAINABILITY**

**Ronald S. Bush-Lieutenant, United States navy**

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**and**

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**Master of Science in Operations Research-September 1996**

**Advisor: Wayne P. Hughes, Jr., Department of Operations Research**

**Second Reader: Charles N. Calvano, Department of Mechanical Engineering**

The arsenal ship program is unique and requires examining the possible features of a paradigm shift in ship design. This thesis presents a user-friendly model with which a decision maker can perform tradeoff analyses between adding specific systems and technologies to the arsenal ship or adding the escort services of combatant ships. The goal of the model is to produce configuration alternatives with high arsenal ship survivability subject to a budget constraint. The model also examines operational logistics by predicting the sustainability of forces with specified arsenal ship configurations. As some inputs are necessarily speculative at this stage, the model is formatted parametrically to facilitate easy updating. A balanced arsenal ship design incorporating point defense, stealth, and hardening is the most attractive choice for littoral operations when life cycle costs are considered. The naval component must also be balanced, reinforcing the notion that stealth and staying power are important in an arsenal ship task force containing DDG-51s and SC-21s.

### **SUITABILITY OF BOX-JENKINS MODELING FOR NAVY REPAIR PARTS**

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**Second Reader: Lyn Whitaker, Department of Operations Research**

A basic function in the proper management of repair part inventories is the forecasting of future demand. The Navy maintains a database of univariate demand data for its repair part inventories using a quarterly time interval. Historically, Navy repair part demand forecasting has been done using the exponential smoothing procedure. This method is a simple and robust means of forecasting, however it does not make use of any characteristics of the entire time series such as trend, cycles, presence of outliers, or demand clustering.

This research begins by developing several simple, robust, and dimensionless time series features. These features are used to predict the suitability of Box-Jenkins (ARIMA) modeling. The ARIMA process is a powerful time series modeling and forecasting technique which possesses flexibility for the inclusion of many time series characteristics. This research project develops a predictive model of ARIMA suitability using both classical regression and a modern expert-system statistical package, ModelQuest. A computationally simple means is presented for determining which time series may benefit from the Box-Jenkins methodology. Using ARIMA modeling for time series that show significant benefit will provide a more accurate demand forecast and benefit inventory management.

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### **OPTIMALLY SCHEDULING THEATER MISSILE DEFENSE PROCUREMENT**

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**Master of Science in Operations Research-September 1996**

**Advisor: Robert F. Dell, Department of Operations Research**

**Second Reader: Gerald G. Brown, Department of Operations Research**

The Ballistic Missile Defense organization (BMDO), oversees the procurement of Theater Missile Defense (TMD) systems. Anticipated expenditures for TMD systems are roughly 15 billion dollars (including money already spent) by 2002, and 31 billion dollars by 2010. A Cost and Operational Effectiveness Analysis provides guidance on the most cost effective mix of TMD inventories to procure for defense against both theater ballistic missiles and cruise missiles, but history indicates that cost growth and schedule growth are likely. We develop a mixed integer linear programming model to help BMDO plan resource allocation for procurement of TMD systems. The model selects an optimal procurement strategy from user-supplied alternatives for each TMD system that most closely satisfies yearly budget levels and system fielding requirements. Alternatives are derived from existing procurement schedules by stretching or contracting the schedule and applying basic learning theory. We develop a tradeoff between budget limits and operational requirements that is tied to the cost of exceeding the budget. Using a baseline of existing procurement schedules, we analyze the effects of imposed operational requirements on the budget, and demonstrate how the added flexibility of alternate procurement schedules improves results.

### **AN EVALUATION OF AN ALTERNATIVE SUPPLY SYSTEM TO SUPPORT THE REPUBLIC OF CHINA'S ARMY**

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**Master of Science in Operations Research-March 1996**

**Advisor: Glenn F. Lindsay, Department of Operations Research**

This study examines the effect of a Point of Sales (POS) type of military supply system on the readiness of a typical Republic of China infantry battalion. The study compares the current system against the POS-like system. Chapter II is a background of the current supply system and the alternative system studied in the thesis. Chapter III develops a stochastic model to generate parts availability probability values for the support of three types of equipment assigned to a battalion. Chapter IV uses these probabilities to populate a decision tree for the determination of which system will increase the readiness of the battalion. A GAMS Program is used in Chapter III to generate the probabilities for support and a Decision Support Program (Data) is used to develop the decision tree and for the analysis of the results.

The results were that without considerations of cost savings that may be realized in such a system the POS system produced a small increase in the readiness of the battalion. Chapter V presents the author's conclusions and recommendations for a more detailed and rigorous study of the proposed alternative supply system.

### **AIR DEFENSE ANALYSIS FOR FRATRICIDE PREVENTION**

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**Master of Science in Systems Technology-June 1996**

**Advisor: Wayne P. Hughes, Jr., Department of Operations Research**

**William G. Kemple, Department of Operations Research**

In order to improve and develop tactics, techniques, and procedures (TTP) for the prevention of fratricide, joint air defense *processes* must be analyzed, not just the outcomes (i.e., fratricides themselves). Fratricide does not occur as an isolated incident but as a result of a series of events and processes—a chain of technical or procedural failures and errors—which must be investigated in great detail in order to effectively understand the true cause. Thus, the causes and implications of fratricide are reviewed, as well as the general measures to prevent it. A detailed description of key

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events and processes which characterize joint air defense is presented. A synopsis of the Joint Air Defense Operations/ Joint Engagement Zone (JADO/JEZ) Test Program is included to illustrate past attempts to improve and/or develop TTP and to outline the evolution of joint air defense analysis. Specific reasons *why* experimental methods of analysis are not entirely appropriate for analyzing joint air defense are included. The role of measures of effectiveness is discussed at length; operational considerations and field test constraints are also discussed. The effects of human factors are considered, including the cognitive limitations of human beings in stressful, information-intensive circumstances; environmental variables which affect human performance; and the role of morale, leadership, and esprit de corps. Significant conclusions are summarized and suggestions for improving joint air defense analysis are delineated.

### **MODELING THE EFFECTS OF LOGISTICS UPON GROUND MANEUVER AND COMBAT**

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**B.S., United States Naval Academy, 1989**

**Master of Science in Operations Research-September 1996**

**Advisor: Arnold H. Buss, Department of Operations Research**

**Second Reader: Samuel Parry, Department of Operations Research**

Logistics can substantially affect the directions of warfare campaigns. The types of war material and their flow rates to field units directly impact the campaign outcome. Although many wargaming and combat simulations have been developed, few models implement the detailed effects of logistics flow. This thesis develops a theater level logistics flow model for a Blue force using a forward logistics base that is advancing upon an objective in Red defended territory. The model computes confidence intervals for Blue's short tons of various classes of supply available throughout the campaign. Logistics activity is generated at user defined rates using four periodic and event driven consumption mechanisms: movement, combat, interdiction, and interdiction repair. The model's primary function is receipt, staging, onward movement, and integration for materiel consumed by Blue. The model is implemented in MODSIM, an object-oriented simulation language providing both synchronous and asynchronous events, as well as a rich class of data structures necessary to implement the model. The basic model is replicated to desired confidence and tolerance, with statistics collected for the amounts of the various classes of supply available for the supported units. The model's output includes confidence intervals for the desired measures of effectiveness.

### **MODELING ATTACK HELICOPTER OPERATIONS IN THEATER LEVEL SIMULATIONS**

**Robert S. Hume-Major, United States Army**

**B.S., United States Military Academy, 1985**

**Master of Science in Operations Research-June 1996**

**Advisor: Mark A. Youngren, Department of Operations Research**

**Second Reader: Leroy A. Jackson, U.S. Army Training and Doctrine Analysis Command**

This thesis describes an attack helicopter module for the *Joint Warfare Analysis Experimental Prototype (JWAEP)*, a joint theater level, low resolution stochastic simulation developed at the Naval Postgraduate School. The modeling formulations, required data, and assumptions which are required to portray attack helicopter operations in theater level simulations are presented. The focus for the attack module is the representation of attack helicopter units in the conduct of deliberate attacks; however, many of the models described can be applied to general helicopter operations. The formulations are limited to the major events that occur during an attack helicopter deliberate attack and represent initial research to portray attack helicopter operations in JWAEP.

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### **FACILITY LOCATION USING CROSS DECOMPOSITION**

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Determining the best base stationing for military units can be modeled as a capacitated facility location problem with sole sourcing and multiple resource categories. Computational experience suggests that cross decomposition, a unification of Benders Decomposition and Lagrangean relaxation, is superior to other contemporary methods for solving capacitated facility location problems. Recent research extends cross decomposition to pure integer programming problems with application to capacitated facility location problems with sole sourcing; however, this research offers no computational experience. This thesis implements two cross decomposition algorithms for the capacitated facility location problem with sole sourcing and compares these decomposition algorithms with direct solution using branch and bound. For some problems tested, cross decomposition obtains better solutions in less time; however, cross decomposition does not always perform better than branch and bound due to the time required to obtain the cross decomposition bound that is theoretically superior to other decomposition bounds.

### **USING GENETIC ALGORITHMS TO SEARCH LARGE, UNSTRUCTURED DATABASES: THE SEARCH FOR DESERT STORM SYNDROME**

**David L. Jacobson-Lieutenant, Medical Service Corps, United States Navy**

**B.S., United States Naval Academy, 1986**

**Master of Science in Information Technology Management-September 1996**

**Advisor: Hemant K. Bhargava, Department of Systems Management**

**Second Reader: Donald Gaver, Department of Operations Research**

The Exploratory data analysis problems have recently grown in importance due to the large magnitudes of data being collected by everything from satellites to supermarket scanners. This so-called "data glut" often precludes the effective processing of information for decision-making. These problems can be seen as search problems over massive unstructured spaces. A prototypical problem of this type involves the search, by Department of Defense medical agencies, for a so-called "Desert Storm Syndrome" which involves large amounts of medical data obtained over several years following the Persian Gulf conflict. This data ranges over more than 170 attributes, making the search problem over the attribute space a hard one. We propose the use of genetic algorithms for the attribute search problem, and intertwine it with search algorithms at the detailed data level. Computational results so far strongly suggest that our system has succeeded at the given tasks, requiring relatively few resources. They also have found no indication that a single syndrome or other medical entity is responsible for wide-spread adverse health ramifications among a significant cross-section of Persian Gulf War participants in the CCEP program. There are, however, numerous correlations of exposure/demographic information and associated symptoms/ diagnoses which suggest that smaller groups may share common health conditions based on shared exposure to common health risk factors.

### **AAW EFFECTIVENESS OF THE DD-963 SPRUANCE CLASS DESTROYER: AN ANALYTIC MODEL**

**Richard O. Johns-Lieutenant, United States Navy**

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**Master of Science in Operations Research-September 1996**

**Advisor: W. Max Woods, Department of Operations Research**

**Second Reader: Robert E. Ball, Department of Aeronautics and Astronautics**

A typical naval ship has multiple systems which can be used to defend itself against a cruise missile threat. These systems may consist of surface-to-air missiles, MK 45 guns and the Close-in-Weapon-System to name a few. Until recently each of these system's effectiveness against a cruise missile was assessed independently of the other systems

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onboard the ship. The purpose of this thesis is to develop an overall system effectiveness model for the DD-963 Spruance class destroyer. The model considers the integration of the defensive systems onboard, the availability and reliability of these systems and contains parameters that can be used to incorporate the crew's ability to employ the various weapon systems against a cruise missile threat.

### **ANALYSIS OF RUSSIAN AND SPANISH SUBSKILL TESTING AT THE DEFENSE LANGUAGE INSTITUTE**

**Carlton L. Lavinder III-Lieutenant, United States Navy  
B.S., North Carolina State University, 1989**

**Master of Science in Operations Research-September 1996**

**Advisor: Lyn R. Whitaker, Department of Operations Research**

**Second Reader: Robert R. Read, Department of Operations Research**

The Defense Language Institute is responsible for training military and government service personnel requiring a foreign language skill. Ten Subskill tests have been developed to evaluate the graduating students' language abilities and to determine if they have met the sponsor's Final Learning Objectives. The Subskill tests in some languages have been in place long enough that they can now be studied. This thesis examines these Subskill tests for both Russian and Spanish to determine if the tests have been developed and implemented in a manner to efficiently and consistently discriminate between students of different abilities. Three different issues are treated. The ANOVA is used to identify Subskill tests with significant rater effects and the magnitude of those effects when they are present. Item Response Theory is used to examine the Subskill tests at the question level in order to identify questions that poorly discriminate between students of different abilities. In addition, the ability range that students are tested over is examined. Finally, methods using principal components and multiple regression are used to determine which tests, if any, can be eliminated with an acceptable loss of information about the students.

### **JOINT OFFICER SUPPORTABILITY MODEL: JOINT EDUCATION AND TRAINING OF U.S. NAVY AVIATORS**

**Robert G. Lineberry Jr.-Lieutenant Commander, United States Navy  
B.S., University of Nebraska at Omaha, 1983**

**Master of Science in Management-March 1996**

**Advisor: Paul R. Milch, Department of Operations Research**

The objective of this thesis is to analyze the current joint education and training track of Joint Specialty Officers (JSOs) for U.S. Navy aviators in order to forecast the number of future JSO eligible officers within this community. This thesis will consider two separate training paths for officers to complete in order to become JSO eligible. The path most preferred educates officers prior to assignment to a joint billet. The second path allows officers to complete their joint assignment prior to entering joint education. Recent historical transition, continuation and promotion rates by years of service and pay grade are used to forecast future officer output. These various rates and variables are applied within a PC-based spreadsheet to provide a user friendly joint officer management tool.

## **1996 THESIS ABSTRACTS**

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### **COMPARISON OF BRADLEY M2A2 AND M2A3 USING JANUS**

**Steven Andrew Lovaszy-Captain, Australian Army**

**B.App.Sc., University of Central Queensland, 1990**

**Master of Science in Operations Research-September 1996**

**Advisor: Bard Mansager, Department of Mathematics**

**Robert Read, Department of Operations Research**

**Second Reader: Glen Roussos, U.S. Army Training and Doctrine Analysis Command**

The U.S. Army is currently developing a new variant of the Bradley Fighting Vehicle, the M2A3 also known as the BFVS-A3. The new vehicle will include a number of modifications to the current M2A2 vehicle as a result of combat experience during Operation Desert Storm. The modifications have resulted from a need to upgrade the Bradley Fighting Vehicle System (BFVS) to facilitate enhanced command and control, lethality, survivability, mobility, and sustainability to defeat current and future threat forces.

The purpose of this thesis is to compare the two variants of vehicle in the Pre-test Modeling phase of the Model-Test-Model concept. This thesis used the Janus high resolution combat model, to simulate the vehicles and weapon systems under two scenarios, a Head-to-Head scenario, and a Force-on-Force scenario. The Head-to-Head scenario is a simulation of the future Limited User Test 2 to be conducted by TEXCOM. The Force-on-Force scenario is a simulated battle between a Bradley platoon and a Soviet style tank heavy company.

Data was gathered from the Janus created postprocessor files of the two scenarios. The analysis compared four measures of effectiveness (MOEs), in the areas of detection, engagement, lethality, and survivability. The aim of the analysis was to detect differences between the vehicle variants using the two sample T-test and the Mann-Whitney-Wilcoxon test.

### **AN ALTERNATIVE TESTING METHODOLOGY FOR TOW MISSILE TRAINING SYSTEMS**

**Scott Jeffrey Mack-Major, United States Marine Corps**

**B.S., United States Naval Academy, 1985**

**Master of Science in Operations Research-September 1996**

**Advisor: Dan C. Boger, Department of Systems Management**

**Second Reader: Paul S. Bloch, Department of Operations Research**

This thesis explores alternatives to current testing methodology being applied to two TOW missile training systems. This thesis contends that current program practices do not adequately prove system accuracy or system training value. Research emphasis is placed upon identifying those factors involved in assessing system accuracy that are currently being overlooked. The objective is that future government testing will address system accuracy and training value in detail. Following a description of current techniques, an alternative to current accuracy assessment is presented using the precepts of direct fire gunnery based upon a series of statistical treatments that quantify system accuracy and contract specification compliance. Data collection enhancements, potential test design modifications, and a methodical data analysis plan is presented. An alternative testing scenario is developed based upon the recommended changes in test methodology. Finally, observations and recommendations are provided pertaining to program management of the two TOW missile training systems in an effort to optimize program structure. The underlying premise is that the application of operations research skills to validate system performance will improve the final product fielded to U.S. Marines and Soldiers.



## **1996 THESIS ABSTRACTS**

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### **A METHODOLOGY FOR EVALUATING MINE ACTUATION DATA**

**Luis A. Maldonado-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1988**

**Master of Science in Operations Research-June 1996**

**Advisor: James Eagle, Department of Operations Research**

**Second Reader: William Kroshl, Department of Operations Research**

This thesis develops a methodology for evaluating mine actuation data. Computer models are developed to analyze actuation data obtained from the Mine Warfare Command by fitting various types of actuation curves to the data. For each actuation curve type, maximum likelihood estimates are used to determine those parameters resulting in the greatest probability of obtaining the observed data.

### **METHODS FOR DETERMINING GOALS AND EXPECTATIONS FOR FIELDIED JET ENGINES**

**John A. Malsbury-Lieutenant, United States Navy**

**B.S., Oregon State University, 1984**

**Master of Science in Management-December 1995**

**Advisor: W. Max Woods, Department of Operations Research**

**Second Reader: Donald R. Eaton, Department of Systems Management**

This thesis investigates methods for determining goals and expectations for fieldied jet engines. Some of these methods employ concepts used in Reliability Centered Maintenance (RCM). The procedures developed here can be applied to any fieldied jet engine. The data used by this thesis was extracted from the Naval Aviation Logistics Data Analysis (NALDA) database. The desktop software programs that were used to attain reliability parameters are readily available to any command. The data analysis accomplished here demonstrated that cannibalization of engines has impacted adversely on reliability. A model was developed to determine no-build times for jet engines at the Intermediate Maintenance and Depot level of repair based on engine reliability and the conditional probabilities of survival of significant components of the engine and their specified maximum operating times

### **A STOCHASTIC SIMULATION OF A UNITED STATES NAVAL CONFLICT WITH A LAND-BASED OPPONENT: THE IMPACT OF C<sup>4</sup>ISR**

**Edward R. Martinez-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1989**

**Master of Science in Operations Research-September 1996**

**Advisor: Donald P. Gaver, Department of Operations Research**

**Second Reader: Patricia A. Jacobs, Department of Operations Research**

This thesis develops a low-resolution stochastic simulation model to assess the impact of the intelligence, surveillance and reconnaissance components of C<sup>4</sup>ISR, and strike capabilities on the mission success of a United States carrier battle group (CVBG). The simulation uses a stochastic approach to model a two-day conflict between a CVBG and a land-based enemy which incorporates the randomness and uncertainty inherent in warfare. The simulation is implemented as a C++ computer program to develop a tool to analytically exercise a prospective new system in order to predict its possible effect on combat operations. Experiments were run which simulated a two-day battle in which the United States CVBG sensor availability, sensor accuracy, and weapons availability were varied to study their affect on the outcome of the battle. Statistical analysis techniques are used to quantitatively measure the results of the battle as the sensor and weapon parameters change.

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### **A STOCHASTIC ENHANCEMENT TO THE ANALYST'S WORKBENCH**

**Andrew W. Melton-Lieutenant Commander, United States Navy (Ret.)**

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**Master of Science in Operations Research-September 1996**

**Advisor: Gary R. Porter, Command, Control, and Communications Academic Group**

**Second Reader: Michael P. Bailey, Department of Operations Research**

The Analyst's WorkBench is a deterministic integrated framework developed and used by the Weapons Planning Group at NAWC China Lake. The model has no stochastic capability which requires all analysis to be conducted using parameters based on expected values of occurrence. This thesis develops a stochastic enhancement that can be incorporated in the Analyst's WorkBench. Independent identically distributed (IID) events can be generated by calls to the enhancement as a parametric input. To demonstrate the application of a stochastic process within the Analyst's WorkBench, a test scenario of a ship defense model is developed. A large scale missile attack is simulated deterministically and stochastically to demonstrate the differences of a random probability of successful defense vice an expected value of success. It is shown that the stochastic results provide a more realistic simulation and that the deterministic results overstate the capability of a system subject to random events that can be described by a statistical distribution.

### **A METHODOLOGY FOR DETERMINING STUDENT VALUE IN EXPLOITING AIRLINE RESERVATION TECHNOLOGIES TO IMPROVE NAVY TRAINING QUOTA MANAGEMENT**

**Scott A. Merritt-Lieutenant, United States Navy**

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**Master of Science in Operations Research-September 1996**

**Advisor: Samuel H. Parry, Department of Operations Research**

**Second Reader: Harold J. Larson, Department of Operations Research**

The Navy trains over 350,000 students a year. Quotas for the number of students to train are based on current and projected manning levels, as well as anticipated force requirements. Last year, students awaiting instruction exceeded 1.3 million mandays while, simultaneously, over 25% of the Navy's 330,000 technical training seats went unfilled. The number of unfilled seats in classrooms, coupled with the large number of students awaiting instruction, identified the need to more closely manage the allocation of quotas. The use of yield management has been explored to determine if airline reservation technologies are applicable to solving the Navy training quota management problem. In order to apply yield management to the Navy training problem, the concept of value must be determined as it relates to a student attending a Navy training class. While airlines measure value in revenue generated, the Navy has no way of placing value on a particular student attending a particular class. This thesis identifies a methodology for determining student value within the Navy Training Quota Management System.

### **METHODS FOR DETERMINING PERFORMANCE EXPECTATIONS AND OPTIMAL NO BUILD TIMES FOR FIELDIED JET ENGINES**

**Mark Edward Mlikan-Lieutenant Commander, United States Navy**

**B.S., Pennsylvania State University, 1984**

**B.A., University of Maryland, 1993**

**Master of Science in Management-June 1996**

**Advisor: W. M. Woods, Department of Operations Research**

**Second Reader: Don Eaton, Department of Systems Management**

This thesis investigates methods for determining fieldied jet engine performance goals. Data exported from the Naval Aviation Logistics Data Analysis (NALDA) data base was fitted by a Weibull distribution to obtain the engine probability density function, cumulative density function, mean time between failure, failure rate, and conditional reliabilities. The thesis applies the results of the data analysis by using a commercial software package, Mathcad, to find the solution to an optimizing equation for average maintenance cost per hour of engine critical component operation. The

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solution yields optimum no build times given the component's Hard Time, ratios of several inspection/repair cost factors, and properties of the failure time probability distributions of the engine and component. The goal is to economize resources by inspecting life limited components when they are available after having accumulated a predetermined number of operating hours. The procedures developed can be used for any aircraft engine or any mechanical component with data that can be fitted to a Weibull distribution and with maintenance cost ratios that fit the model presented herein.

### **TOWARD ASSESSMENT OF DOMINANT BATTLESPACE AWARENESS: A REMOTE SENSOR SYSTEM MODEL**

**Kenneth H. Munson, Jr.-Lieutenant, United States Navy**

**B.S., Pennsylvania State University, 1989**

**Master of Science in Operations Research-March 1996**

**Advisor: Donald P. Gaver, Department of Operations Research**

Two broad concepts have begun to permeate U.S. military strategic planning since the end of the Gulf War: the revolution in military affairs (RMA) and dominant battlespace awareness (DBA). An RMA represents a basic change in the conduct of warfare which incorporates new technologies, operational innovation and organizational changes. DBA refers to the military's ability to efficiently obtain and effectively use information to dominate an opposing force. This thesis is a study of a stylized warfare scenario involving elements of DBA and RMA. Specifically, U.S. attack aircraft attempt to prevent enemy transporter-erector-launchers (TELs) from harassing neighboring countries with theater ballistic missiles. The U.S. aircraft may be aided by use of unattended ground sensors (UGSs); the enemy TEL activities are correspondingly enhanced by decoy TELs. The model described allows the combat advantage of each side to be quantitatively compared. Trend analysis demonstrates the benefits of deception and the potential of UGSs.

### **EVALUATING CARRIER BATTLEGROUP ANTI-AIR WARFARE CAPABILITY IN A COMPUTER-AIDED EXERCISE**

**John Burton Mustin-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1990**

**Master of Science in Operations Research-September 1996**

**Advisor: Sam Parry, Department of Operations Research**

**Second Reader: George Conner, Department of Operations Research**

One of the primary training tools available to a Unified Commander in Chief (CINC) for training his staff on their joint mission essential tasks (JMETLs) is a command post exercise supported by a computer simulation model, commonly referred to as a Computer Aided Exercise (CAX). Currently, little quantitative data are captured during the exercise allowing for quick postexercise analysis of critical staff processes inherent in the CINC's exercise training objectives. The objective of this thesis is to develop an exercise analysis methodology for evaluating the execution of joint tasks during the conduct of a CAX. Specific objectives are first to demonstrate a methodology for developing quantifiable measures of effectiveness (MOEs). These MOEs must reflect the hierarchical structure of tasks given in the Universal Joint Tasks List (UJTL) as applied to three levels of war (vertical linkage), and functionality considerations between related enabling tasks (horizontal linkage). The second specific objective is to determine methods to capture task performance data within the design of the simulation. This is intended to support the exercise analysis by capturing critical decisions, assumptions, and causal factors which, in turn, lead to observed scenario outcomes. This objective involves demonstrating the methodology in an exercise conducted utilizing the Joint Theater Level Simulation (JTLS). The effort in this thesis is focused exclusively on joint tasks involving force protection, particularly air defense, of a battlegroup in the littoral region; however, the principles of the methodology are applicable to the entire spectrum of tasks in the UJTL.

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### **APPLICATIONS OF LOGISTIC REGRESSION TO IDENTIFY FACTORS THAT AFFECT THE MEASURES OF THE ARMY PERSONNEL READINESS**

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**B.S., United States Military Academy, 1987**

**Master of Science in Operations Research-September 1996**

**Advisor: Glenn F. Lindsay, Department of Operations Research**

**Second Reader: James R. Thomas, PERSCOM**

The purpose of this thesis was to use regression models to investigate factors that might be used to predict the monthly aggregated measures of Army personnel readiness. To that end, logistic regression analysis was conducted using Army personnel data that ranged from October 1991 thru September 1995. There were two measures (or response variables) for this study; the proportion of Army units with personnel ratings at least as high as their Authorized Level of Organization, and the proportion of Army units that achieved a personnel rating of 3 or better. In an attempt to identify potential factors that may influence these measures, ten covariates were selected for the analysis. This analysis focused primarily on the development of six logistic regression models that were used to forecast the two readiness measures one month, two months, and three months into the future. The results of this study may benefit Army personnel managers by providing them with an increased understanding of the factors that significantly affect the two quantifications of Army personnel readiness.

### **UNITED STATES MARINE CORPS MILITARY OCCUPATIONAL SPECIALTY (MOS) ASSIGNMENT MODELING USING AUGMENTATION PROBABILITIES**

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**B.S., Pennsylvania State University, 1990**

**Master of Science in Operations Research-March 1996**

**Advisor: William G. Kemple, Department of Operations Research**

An assignment model is developed which considers augmentation probabilities when assigning Marine officers Military Occupational Specialties (MOSs) at The Basic School (TBS). The goal is to increase the expected number of augmentees in those MOSs that are chronically short in company and field grade officers. Results are compared to the current process of assigning MOSs based on a "quality spread" achieved by dividing the TBS class and MOSs available into thirds and to a similar policy of division into halves.

Regardless of the model used, the expected number of augmentees does not vary appreciably from the historical averages. Not adhering to the quality spread policy in the past has not impacted augmentation probabilities greatly. Dividing the class into halves vice thirds provides approximately the same expected number of augmentees as the current policy and would give more officers from the top of the class one of their top choices. The only other change to assignment policy which may be warranted is restricting assignment for several MOSs (MOS 4002-data processing, 7208-air defense, and 7210-air support) to assignment from the top third or half of the class.

### **THE USE OF PATROL CRAFT IN LOW INTENSITY CONFLICT OPERATIONS: AN ALTERNATIVE MODEL FOR THE EMPLOYMENT OF THE *CYCLONE*-CLASS (PC-1)**

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**B.S., United States Naval Academy, 1990**

**Master of Arts in National Security Affairs-December 1995**

**Advisor: Wayne P. Hughes, Jr., Department of Operations Research**

The post-Cold War era has posed a significant challenge to the U.S. Navy. The absence of a major, blue-water, naval threat has allowed the Navy to shift its focus toward the littoral arena and to develop strategies and tactics for operations close to shore. While it is hard to dispute the need for the combat power of a carrier battle group in wartime, its firepower is less necessary or applicable in low intensity conflict (LIC) operations. Patrol craft, particularly *Cyclone*-class (PC-1), are ideally suited for LIC. These "niche" craft offer a valuable contribution to the close-in, coastal patrol

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and interdiction mission and to naval special warfare support.

Unfortunately for the PCs, the institutional bias of the U.S. Navy favors multi-mission capable "big ships" and small craft programs are often deemed non-competitive and are ignored. The thesis examines this problem through the lens of bureaucratic politics theory and uses it to compare the similarity of arguments for and against the PHM and PC programs. In an attempt to create an alternative model PC employment, based on a mother ship/scout-fighter concept, the thesis also investigates how foreign coastal navies employ their patrol craft. The study concludes with a recommendation to more heavily involve the PCs in LIC and contingency operations and make them part of the Navy's forward presence mission.

### **DETERMINING AN OPTIMAL BULK-CARGO SCHEDULE TO SATISFY GLOBAL U.S. MILITARY FUEL REQUIREMENTS**

**Jorge E. Quiroga-Lieutenant, United States Navy**

**B.S., San Jose State University, 1988**

**Master of Science in Operations Research-September 1996**

**and**

**Jason T. Strength-Lieutenant, United States Navy**

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**Master of Science in Operations Research-September 1996**

**Advisor: Dan Boger, Department of Systems Management**

**Second Reader: Bob Vassian, Department of Operations Research**

The Defense Fuel Supply Center (DFSC) is responsible for the acquisition, storage, and distribution of bulk petroleum products to support worldwide military service requirements. DFSC delivers these fuel products around the globe through a fleet of bulk-cargo tankers which are controlled by Military Sealift Command (MSC). The current method of scheduling cargo deliveries is done manually and takes approximately three to five days to complete, requiring close interaction with MSC. The cargo scheduling planners must specify a feasible load port and time, and discharge port and time for each cargo such that military fuel demands are met and the tankers are utilized efficiently. Currently, there are no mathematical models available to assist scheduling planners in assigning an efficient cargo schedule.

The objective of this thesis is to aid scheduling planners in determining the most efficient cargo sequencing plan. This is achieved through the development of a mathematical model which represents the cargo scheduling problem, and the design of a microcomputer interface that allows use of the model as a management tool which seeks to maximize the number of cargo deliveries. Specifically, an optimization model utilizing the network structure of the maximum flow model, which is accessed through a spreadsheet-based interface, is used to solve the cargo scheduling problem.

### **A REACTIVE TARGET ACTIVE ASW SONAR SEARCH TACTICAL DECISION AID**

**Cesar J. Recalde, Argentine Navy**

**Argentine Naval Academy, 1984**

**Master of Science in Operations Research-September 1996**

**Advisor: Alan Washburn, Department of Operations Research**

**Second Reader: James Sanders, Department of Physics**

This thesis develops, implements and tests a Tactical Decision Aid for a Reactive Target ASW Active Search. The model uses a Bayesian Filtering Process to fuse information from a real world search conducted by several assets with information from a Monte Carlo Simulation that encompasses five hundred equally-likely different possible initial positions and behaviors of the real target. A Reactive Target Model resembles the behavior of a target that is always aware and reacts because of the presence and activity of the searchers. An initial "prior," or best estimate of the location of the target, is updated using the movement of the simulated targets, the negative information conveyed in an unsuccessful search over a period of time and the positive information implied in a contact report. The search effort is measured using a Fixed Scan Stochastic Model that solves the Sonar Equation limited by noise and reverberation. As

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a result of updating the prior, a "posterior" distribution is obtained. The Law of Total Probabilities is used to render a probability map of the location of the Target by mapping color intensities to probabilities. A recursive expression for evaluating a contact report is also developed.

### **ANALYSIS OF THE AIRCRAFT CARRIER ELECTRIC MOTOR REPAIR SHOP USING SIMULATION AND ANIMATION**

**Jeffrey A. Richardson-Lieutenant, United States Navy**  
**B.S., Southern Illinois University at Carbondale, 1994**  
**Master of Science in Operations Research-September 1996**  
**Advisor: Keebom Kang, Department of Systems Management**  
**Second Reader: Arnold H. Buss, Department of Operations Research**

While operating within the Battle Force Intermediate Maintenance (BFIMA) Activity, emergent maintenance requests issued by ships in company with the carrier for motor rewind and overhaul work naturally occur whenever other suitable and better equipped maintenance assets such as tenders or nearby shore facilities are not available. To evaluate the capability of the carrier's electric motor repair shop to support the BFIMA, a simulation and animation model of the repair process was developed. The model computed the mean number of rewinds and overhauls and their average repair turnaround times as shop resource levels and arrival rates varied during one 6 month deployment. The analysis shows that addition of another bake oven improves readiness by significantly reducing mean repair times.

### **OPTIMIZATION METHODS FOR MIXED MINEFIELD CLEARANCE**

**David D. Romberger-Lieutenant, United States Navy**  
**B.S.N.A., United States Naval Academy, 1988**  
**Master of Science in Operations Research-September 1996**  
**Advisor: Alan R. Washburn, Department of Operations Research**  
**Second Reader: James N. Eagle, Department of Operations Research**

This thesis describes the development and implementation of an improved optimization feature for the minefield clearance TDA MIXER. A constrained form of MIXER's original local optimal search method is proposed, followed by an exhaustive search method, and then a simulated annealing method.

Computational efficiency and program run times are examined for the exhaustive search method. Also, a performance comparison of "optimal" solutions for the local search and simulated annealing methods is given. A final version of the optimization feature incorporates all three search methods.

### **AN ASSESSMENT OF THE IMPACT OF FUSED MONOCHROME AND FUSED COLOR NIGHT VISION DISPLAYS ON REACTION TIME AND ACCURACY IN TARGET DETECTION**

**Matthew Thomas Sampson-Captain, United States Marine Corps**  
**B.S., United States Naval Academy, 1987**  
**Master of Science in Operations Research-September 1996**  
**Advisors: William Krebs, Department of Operations Research**  
**Robert Read, Department of Operations Research**  
**Second Reader: Thomas Halwachs, Department of Operations Research**

Night Vision Devices (NVDs) employed by the military fall into two categories: Image Intensifiers ( $I^2$ ) also known as Night Vision Goggle (NVGs) and Infrared (IR). Each sensor provides unique visual information not available to the unaided human visual system. However, these devices have limitations and they have been listed as a causal factor in many crashes of military aircraft at night. Researchers hypothesize that digitally fusing the output from these sensors into one image and then artificially coloring the image will improve an NVD user's visual performance. The purpose of this thesis was to determine if fusion and coloring of static, natural scene NVG and IR imagery will improve reaction

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time and accuracy in target detection.

Pairs of static images from three different scenes were obtained simultaneously from NVG and IR sensors. The six original images were fused pixel by pixel and then colored using a computer algorithm. A natural target was moved to two other coherent positions in the scene or completely removed, resulting in twenty-four images for each of the three natural scenes. Six subjects viewed the images randomly on a high-resolution monitor, rapidly indicating on a keypad if the target was present (1) or absent (2). Reaction time and accuracy were recorded. An ANOVA on the output and a subsequent review of the images revealed that fusion significantly impacted local (target) contrast and that, coupled with scene content, decreased performance on the task. Fusion and coloring results were not superior here, which differed from results on other types of tasks, however, more research is needed to completely assess this technology.

### **RELATING THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY TO MARINE JOB PERFORMANCE**

**Robert Joseph Schaffer III-Captain, United States Marine Corps  
B.S., The University of Illinois at Champaign, 1990**

**Master of Science in Operations Research-September 1996**

**Advisor: Robert R. Read, Department of Operations Research**

**Second Reader: Harold J. Larson, Department of Operations Research**

This thesis develops a method to reconfirm the relationship between an individual's Armed Services Vocational Aptitude Battery (ASVAB) scores and his performance at his initial course of instruction in the Marine Corps. Validity coefficients are developed to ensure that the ASVAB correctly predicts success at these initial training courses. Once the ASVAB is shown to correctly predict success at Marine Corps courses, the thesis concentrates on two statistical methods to explore the classification of youths into marine jobs. The first method, discriminant analysis, is used as a check of the current classification process. Next, a tree-based regression method is used to evaluate if further employment of ASVAB scores can more appropriately place trainees into Marine Corps jobs. These methods ultimately afford the Marine Corps an opportunity to use existing information to enhance the successful classification of young Marines into appropriate courses, thereby increasing their chances of successfully completing their initial training.

### **OPTIMAL AIRCRAFT CARRIER DEPLOYMENT SCHEDULING**

**Craig T. Schauppner-Lieutenant, United States Navy  
B.A., University of California Los Angeles, 1988**

**Master of Science in Operations Research-March 1996**

**Advisor: Siriphong Lawphongpanich, Department of Operations Research**

The Navy's peacetime mission is "to conduct forward presence operations to help shape the strategic environment by deterring conflict, building interoperability, and by responding, as necessary, to fast breaking crises with the demonstration and application of credible combat power." To meet this mission, the Navy deploys aircraft carriers to forward positions throughout the world. A new nuclear powered aircraft carrier costs over \$3.4 billion dollars and when deployed carries over 6,000 personnel onboard. Considering the cost and the man hours involved in carrier operations, judicious and effective use of these valuable assets is imperative.

The CINCPACFLT Operations Department maintains a five year deployment plan for the six carriers assigned to the Pacific Fleet. Currently, the deployment schedule is produced manually. A feasible five year plan typically takes the carrier scheduling officer one week to generate. This thesis presents an optimization based tool to assist in constructing deployment schedules that maximize the forward presence of Pacific Fleet carriers. The underlying optimization model is different from those in the literature. Instead of using a set covering approach, the problem is formulated as a shortest path problem with side constraints. This formulation allows the problem to be solved more rapidly, thus allowing more opportunities for sensitivity and trade-off analyses.

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### **STRATEGIC SEALIFT PROTECTION IN A MAJOR REGIONAL CONFLICT**

**Gordon Alexander Silloway-Lieutenant, United States Navy**

**B.A., University of Southern California, 1989**

**Master of Science in Operations Research-September 1996**

**Advisor: Wayne Hughes, Department of Operations Research**

**Second Reader: Al Bottoms, Undersea Warfare Academic Group**

This thesis examines the North Korean threat to U.S. strategic sealift in a single major regional conflict (MRC) on the Korean peninsula. The focus of this campaign level analysis is the ability of U.S. and Korean maritime patrol aircraft (MPA) to intercept North Korean Romeo-class attack submarines as they operate in South Korean waters. An MPA search model is developed which details current tactics and operating parameters for the P-3C Orion patrol aircraft. Results obtained from this model are expressed as the probability that a North Korean submarine in a special geographic sector will be detected and destroyed on any given day of the campaign. Two alternative means of conducting anti-submarine operations in the Korean MRC are also presented. Campaign and tactical level recommendations are made based on the information provided by the analysis.

### **DEVELOPMENT OF A FORCED ENTRY MISSION OBJECTIVE SELECTION ALGORITHM FOR IMPLEMENTATION INTO THE JOINT WARFARE ANALYSIS EXPERIMENTAL PROTOTYPE**

**William Nicholas Allen Slavik-Captain, United States Marine Corps**

**B.S., Rice University, 1988**

**Master of Science in Operations Research-December 1995**

**Advisor: Samuel H. Parry, Department of Operations Research**

This thesis develops an algorithm for the selection of objectives for forced entry military operations in a theater level campaign model. The Joint Warfare Analysis Experimental Prototype (JWAEP) is an interactive, 2-sided, theater-level combat model based on an arc-node representation of ground, air, and littoral combat. It may be used in an interactive gaming mode or a closed-form stochastic analysis mode. The need for active mission assignment in the analysis mode mandates that objectives for combat operations be nominated during each planning cycle to adapt to the changing face of the battlefield. JWAEP would execute an initial feasibility check for enemy occupied or controlled nodes against the assets available to the friendly forces. Based on the probabilistic representation of the enemy units occupying a node, the algorithm determines the relative value of perceived maneuver units and static targets. This is then compared to the relative perceived strength of the units in that node and surrounding nodes which may also defend against the operation. The perceived strength determines the threat; it is calculated for each force capable of executing the attack. The most desirable node for each force, given value and threat, is sent to the appropriate planning module. The principal focus of this thesis is on the determination of the target value parameter and the node defensibility parameter as they are used to nominate and rank possible objectives.

### **PROBABILITY MODELS FOR ASSESSING THE VALUE OF BATTLE DAMAGE ASSESSMENT IN THE DEFENSE AGAINST SEQUENTIAL THEATER MISSILE ATTACKS**

**Shing-Jen Song-Lieutenant Commander, Republic of China Navy**

**B.S., Chinese Naval Academy, 1987**

**Master of Science in Operations Research-March 1996**

**Advisor: Donald P. Gaver, Department of Operations Research**

This thesis seeks to use probability models to investigate the effects and value of battle damage assessment (BDA) information availability on sequential tasks encountered in the defense against missile attacks. Different levels of information will have different impacts on the outcome of the battle. Additional information could increase the effectiveness of the defensive weapon system. On the other hand, the enemy could use deception techniques, electronic warfare (EW) and Decoy measures on the information gathering methods to disrupt the acquisition of information which would decrease the effectiveness of defensive weapons. In the models, we show how to best allocate limited



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resource; i.e., the available kill time, to maximize the reward. We define a measure of effectiveness (MOE) for information which can be used for evaluating information value and decision making. We discuss different strategic alternatives and information value for both defenders and attackers in electronic warfare (EW).

### **PERFORMANCE MEASURE ANALYSIS OF COMMAND AND CONTROL ORGANIZATIONAL AND TASK STRUCTURES**

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**Master of Science in Operations Research-September 1996**

**Advisor: William G. Kemple, Department of Operations Research**

**Second Reader: Michael G. Sovereign, Department of Operations Research**

Recent joint operations such as the ones in the Persian Gulf, Somalia, Haiti, and Bosnia are examples of some of the missions the military is expected to conduct in the future. The missions and available forces varied, and not surprisingly, so did the command and control architectures.

The purpose of the initial A2C2 experiment was to examine the relationships between organizational structures and task structures involving competition for scarce assets, to serve as an integration vehicle for the project's previous efforts, and as a baseline for further research. This thesis attempts to answer the following questions: 1) Are there statistically significant differences in the outcomes of competition events based on the particular experimental conditions imposed? and 2) Is there a viable method for determining the processes involved in the resolution of competition events, and can it be accomplished without the use of human monitors, i.e., can a tool be developed to determine the processes used in the resolution of competition events after an experiment is conducted?

The answer to both questions is yes; although in the case of the first question, a qualified yes. Programs the author developed to satisfy the second question are included.

### **SENSORS IN OBJECT ORIENTED DISCRETE EVENT SIMULATION**

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**Second Reader: James Eagle, Department of Operations Research**

The growing cost of physical tests and evaluations of military systems has resulted in increased use of computer simulations to provide decision support information. Many such systems, such as weapons and countermeasure systems, rely on sensors. Hence, development of widely applicable computer models for sensors is vitally important. This research investigates the possibility of developing sensor simulations as components for use in models with varying fidelity and purpose. Development of abstractions is emphasized to maximize the applicability of components in a variety of modeling contexts. Concrete examples of reusable sensor components are demonstrated in working models and a preliminary design for a generalized modeling framework is proposed.

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### **ANALYSIS OF DEFENSE LANGUAGE INSTITUTE'S AUTOMATED STUDENT QUESTIONNAIRE DATA**

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**Second Reader: Lyn R. Whitaker, Department of Operations Research**

This thesis explores the dimensionality of the Defense Language Institute's (DLI) primary student feed back tool - the Automated Student Questionnaire (ASQ). In addition, a data set from ASQ 2.0 (the newest version) is analyzed for trends in student satisfaction across the sub-scales of sex, pay grade, and Defense Language Proficiency Test (DLPT) results.

The method of principal components is used to derive initial factors. Although an interpretation of those factors seems plausible, they are subjected to a factor analysis rotation (varimax) and five factors are determined and interpreted in terms of student satisfaction with DLI's: (1) academic environment, (2) military environment, (3) non-bar-racks dormitory living conditions, (4) official and supplemental course audio tapes, and (5) service unit's computer learning centers. From the factor loading matrix factor scores equations are developed for use in a sub-scale trend analysis.

Using non-parametric procedures, each factor is checked for differences in central tendency by sex, pay grade, and DLPT score (DLPT consists of three tests DLPTL, DLPTR, DLPTS). From this analysis the following results derive: (1) sex has no effect on any of the factors, (2) pay grade affects satisfaction with the military environment, and (3) DLPTL, DLPTR, and DLPTS affect satisfaction with the academic environment, and DLPTS also affects satisfaction with the computer learning centers.

### **A METHODOLOGY FOR EVALUATING A JOINT MOBILIZATION PLAN USING THE JOINT THEATER LEVEL SIMULATION (JTLS)**

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**Second Reader: Greg Brouillette, Joint Warfighting Center**

One of the primary training tools available to a Joint Commander in Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. Computer-Aided Exercises (CAXs) are an essential part of training a component staff, however one weakness lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise, and not only is no quantitative data captured but in most cases they don't receive a detailed debrief. This research presents a methodology for evaluating the performance of joint mobilization tasks as set forth in the Universal Joint Task List (UJTL). The UJTL provides both the staff and evaluators with a common document outlining the critical events and activities which require successful accomplishment. The UJTL is organized in such a manner which defines activities such as logistics, intelligence, and force protection.

It is the purpose of this thesis to provide a methodology for objectively assessing the effectiveness of a staff's joint mobilization plan. Experimental runs using the Joint Theater Level Simulation (JTLS) are presented to demonstrate the methodology and the subsequent analysis process.

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### **DETECTABILITY OF THE MEDIUM ALTITUDE ENDURANCE UNMANNED AERIAL VEHICLE (MAE UAV) "PREDATOR"**

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**Michael G. Sovereign, Department of Operations Research**  
**Second Reader: Mark Youngren, Department of Operations Research**

This thesis assessed the detectability of the Medium Altitude Endurance Unmanned Aerial Vehicle (MAE UAV) "Predator," in support of Advanced Concept Technology Demonstration (ACTD) objectives for the Defense Evaluation Support Activity. The scope of this thesis is limited to the Predator air vehicle utilized in a high-intensity scenario against a "Soviet" low-altitude air defense threat.

The thesis presents a detailed analysis of both threat characteristics and air vehicle signature data required to support the detectability analysis. The analysis utilizes Digital Integrated Modeling Environment air defense models and all source reporting to draw and present conclusions on the detectability of the air vehicle and the effect of detection on mission accomplishment.

This thesis is intended to provide direct input into the ACTD, providing the future users with detection data needed to develop doctrinal risk assessment tools against which to make deployment decisions for the MAE UAV. The results of this study may serve as a reference in the long term development of MAE UAV tactics, techniques, and procedures by future users. Results may additionally be used to enhance future vulnerability assessments.

### **A METHODOLOGY FOR EVALUATING FORCE PROTECTION DURING A COMPUTER-AIDED EXERCISE**

**John Lewis Thurman-Captain, United States Army**  
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**Master of Science in Operations Research-September 1996**  
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**Second Reader: Gregory Brouillette, Joint Warfighting Center**

The development of a proficient staff at the Joint Level is primarily accomplished through the use of computer-aided exercises (CAXs). The primary purpose of these exercises is to increase the readiness of the staff to perform actual missions from standing up a Joint Task Force (JTF) to redeployment of the forces. A measure of the tasks required of a staff is accomplished through a Mission Essential Task List from the Universal Joint Task List (UJTL). This document defines critical events and activities that must be accomplished to achieve the desired mission goals. The measurement of that performance from actual data from the computer model has been limited. This thesis provides a methodology that assists in the evaluation of force protection. This quantitative analysis can be provided quickly and concurrent to the exercise. Immediate feedback helps the staff and commander to understand why an outcome happened through linkage of UJTL tasks. This methodology was tested using the Joint Theater Level Simulation and the results demonstrating the methodology and analysis of the output are presented.

### **POSITIONING AND TRANSPORTING AMMUNITION IN SUPPORT OF THE DUAL MAJOR REGIONAL CONTINGENCY SCENARIO**

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**Master of Science in Operations Research-December 1995**  
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This study is concerned with the problem of optimizing the transportation of select ammunition types in support of the dual Major Regional Contingency (MRC) scenario. The purpose is to provide decision makers with alternative courses

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of action when transporting ammunition in this scenario and the problems that may be encountered. The tool used to accomplish this goal is an optimization model developed and implemented using the General Algebraic Modeling System (GAMS). The model optimally routes and schedules the ammunition distribution ships serving in this scenario. The ships used are a mix of Navy controlled ammunition ships (AK) and ships of the Ready Reserve Force (RRF). To examine the problems associated with the distribution of ammunition in this scenario, four cases were developed. Analysis of these cases with the optimization model investigated three main problems associated with the distribution of ammunition in the Western Pacific (WESTPAC) in support of the dual MRC scenario. These problem areas are: insufficient supply of ammunition at the supply ports, inadequate numbers of ships available to move ammunition, and a decrease in the ability of a supply port to handle ammunition. All of these problems will affect the Navy's ability to conduct its missions in support of the dual MRC scenario.

### **ROUTE, AIRCRAFT PRIORITIZATION AND SELECTION FOR AIRLIFT MOBILITY OPTIMIZATION**

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**Master of Science in Operations Research-September 1996**

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**Steven F. Baker, United States Air Force**

**Second Reader: David P. Morton, University of Texas at Austin**

The *Throughput II* mobility optimization model (Morton, Rosenthal, and Lim, 1995) was developed at the Naval Postgraduate School for the Air Force Studies and Analysis Agency (AFSAA). The purpose of *Throughput II* is to help answer questions about the ability of the USAF to conduct airlift of soldiers and equipment in support of major military operations. Repeated runs of this model have helped AFSAA generate insights and recommendations concerning the selection of aircraft assets. Although *Throughput II* has earned the confidence of AFSAA, repeated applications are hampered by the fact that it can take over three hours to run on a fast workstation. This is due to the model's size; it is a linear program whose dimensions can exceed 100,000 variables, 100,000 constraints, and 1 million nonzero coefficients, even after extensive model reduction techniques are used. The purpose of this thesis is to develop heuristics that can be performed prior to running *Throughput II* in order to reduce the model's size. Specifically, this thesis addresses the fact that the *Throughput II* formulation has many variables and constraints that depend on the number of available routes for each aircraft. The goal is to carefully eliminate routes so as to make the problem smaller without sacrificing much solution quality.

### **AIRFIELD AGGREGATION AND ROUTE SELECTION METHODS FOR STRATEGIC AIRLIFT**

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**Master of Science in Operations Research-December 1995**

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Due the remarkable growth in the size and complexity of airlift operations, there is an increased need for planning tools to assist decision makers with issues ranging from selecting the number and types of aircraft for an airlift fleet to making informed decisions with respect to investing or divesting in overseas air bases. In Fiscal Year (FY) 94 research was initiated in the Operations Research Department of the Naval Postgraduate School in response to a request from the United States Air Force Studies and Analyses Agency and resulted in the development of a high fidelity strategic airlift optimization model called *Throughput II*. The model is formulated as a multi-period, multi-commodity linear programming model for determining the maximum on-time throughput of cargo and passengers that can be transported with a given fleet or given network, subject to appropriate physical and policy constraints. Troop and equipment movement requirements are specified by the Time Phase Force Deployment Data (TPFDD). An optimization model that utilizes the full level of detail available in a TPFDD would be of intractable size. Moreover, it is not necessary to build a model with such a fine level of detail in order to obtain the important insights required to assist decision makers.

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Therefore *Throughput II* replaces the potentially large set of airfields with a smaller set of centroids and schedules aircraft through these aggregated airfields. Currently route selection is performed manually, by an expert, who incorporates a variety of factors based on his/her experience. In this thesis we develop techniques for selecting a set of candidate routes for any deployment scenario without requiring historical data or extensive interaction with an expert. An analyst should be concerned about two potentially detrimental effects of these preprocessing procedures. First, unfeasibility may be introduced by aggregation and second, *Throughput II* may provide suboptimal solutions since we consider a limited number of routes. To address these issues, a postprocessing step can be used to screen for constraint violations and to perform sensitivity analysis with respect to alternative routing options.

### **LONG RANGE INTER DEPLOYMENT TRAINING CYCLE SCHEDULE FOR THE P-3 COMMUNITY**

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**Second Reader: George W. Conner, Department of Operations Research**

The P-3 community consists of 12 Active (effective 01 Oct 96) Maritime Patrol Aviation (MPA) squadrons which deploy to various parts of the world conducting numerous missions. Before deployment, each squadron undergoes a work-up period called the Inter-Deployment Training Cycle (IDTC). The purpose of the IDTC is to adequately prepare a squadron for deployment by conducting training, inspections, and evaluations. A plan is developed to schedule squadron and wing assets effectively to ensure quality training that will improve operational effectiveness on deployment.

The difficulty is developing an IDTC schedule for an individual squadron that has minimal impact on the other eleven squadrons. A schedule that efficiently coordinates a squadron's IDTC improves the effectiveness of a squadron. Moreover, a master schedule that considers the community as a whole will improve the overall effectiveness of the community.

This thesis develops a master schedule for the P-3 community that efficiently schedules an IDTC at the squadron level staying within the desires of the squadron commanders. Additionally, an IDTC shell is incorporated into the employment plans throughout the community avoiding conflicts at all levels. Significant savings are gained by optimally scheduling the NATOPS evaluations.

### **A COMPARISON OF AIRCRAFT DEPOT INDUCTION PROCESSES: ASPA AND PDM**

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**Donald Eaton, Department of Systems Management**

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The purpose of this thesis is to compare two predominant decision processes for aircraft depot inductions. The first process, Aircraft Service Period Adjustment (ASPA), is currently applied to the majority of Naval aircraft. The decision to induct an aircraft through ASPA is based on the results of subjective, periodic inspection. The second process, Programmed Depot Maintenance (PDM), is used by the U.S. Air Force. The Navy is also experimenting with its own form of PDM, called Phased Depot Maintenance. The PDM concept is based on the idea that regular overhaul of aircraft reduces man-hour requirements, turn-around time, and the variability of planning factors. The decision to induct an aircraft under PDM is entirely objective, as it is based solely on calendar time. A statistical comparison of the long term effects of ASPA and PDM is achieved by analyzing the output data of a simulation model designed in this thesis. Model output includes maintenance man-hour and turn-around time per depot overhaul, and the cumulative time in the depot and number of depot periods over the length of the simulation. The analysis provides insight into the benefits and trade-offs involved with each decision process.

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### NAVAL DOCTRINE: AN ANALYSIS OF THE EFFECTIVENESS OF NDP 1 AND NDP 6

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Master of Science in System Technology-June 1996

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William G. Kemple, Department of Operations Research

The purpose of doctrine is to unite beliefs and actions. The Armed Forces are not always successful in achieving true interoperability; one cause for the disconnection between them is that, while the Services develop forces, they do not employ them. The Combatant commands employ what the Services provide. Accordingly, one of doctrine's most valuable roles is assuring the integration of developer and operator. This thesis examines the successfulness of Naval and Joint Warfare and Command and Control doctrine at the interface of development and employment.

The thesis concludes that Joint Publication 1, *Joint Warfare of the US Armed Forces*, and Joint Publication 6, *Doctrine for Command, Control, Communications, and Computer (C4) Systems*, present an integrated, focused framework. The ties to (and between) the corresponding Naval Doctrine Publications are weaker. Naval Doctrine Publication 1, *Naval Warfare*, the Naval Doctrine Command's first attempt at issuing doctrine, contains several weaknesses that detract from its stated purpose of establishing a framework for more detailed doctrine. Naval Doctrine Publication 6, *Naval Command and Control*, does meet its purpose and is a much stronger document, but could be further strengthened by incorporating a discussion of how Naval Command, Control, Communications, Computers, and Intelligence systems will be employed to support Naval Command and Control.

### VALIDATING AND IMPROVING EXISTING JLOTS THROUGHPUT MODELS WITH THE USE OF HISTORICAL WEATHER DATA

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The practice of Joint Logistics Over the Shore (JLOTS), whereby strategic sealift assets are off-loaded without the benefit of fixed port facilities has emerged as one viable technique which could alleviate certain situational sustainment problems. The ability to successfully conduct JLOTS operations, however, is presently limited by several factors, the most significant of which is the dependency of JLOTS operations upon favorable wind, weather, and sea state conditions. Presently, the few analytical JLOTS throughput models in existence have very limited incorporation of environmental parameters.

With this in mind, this thesis attempts to both validate and improve the most widely acclaimed JLOTS throughput model, the Joint Over the shore Transportation Estimator (JOTE) developed by the Logistics Management Institute (LMI). The validation centers upon identifying the demands placed upon the user when employing JOTE as well as assessing the validity of its computational methodology. As a means of improving JOTE and rendering it more viable as a planning tool, this thesis introduces a supplement entitled the SEA-STATE-CALC package which facilitates both site and time specificity in the most crucial input parameters to the JOTE model. By helping to identify time periods in which sea state conditions threaten JLOTS operations, the SEA-STATE-CALC package services the planning needs of its true client, the JLOTS commander.

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